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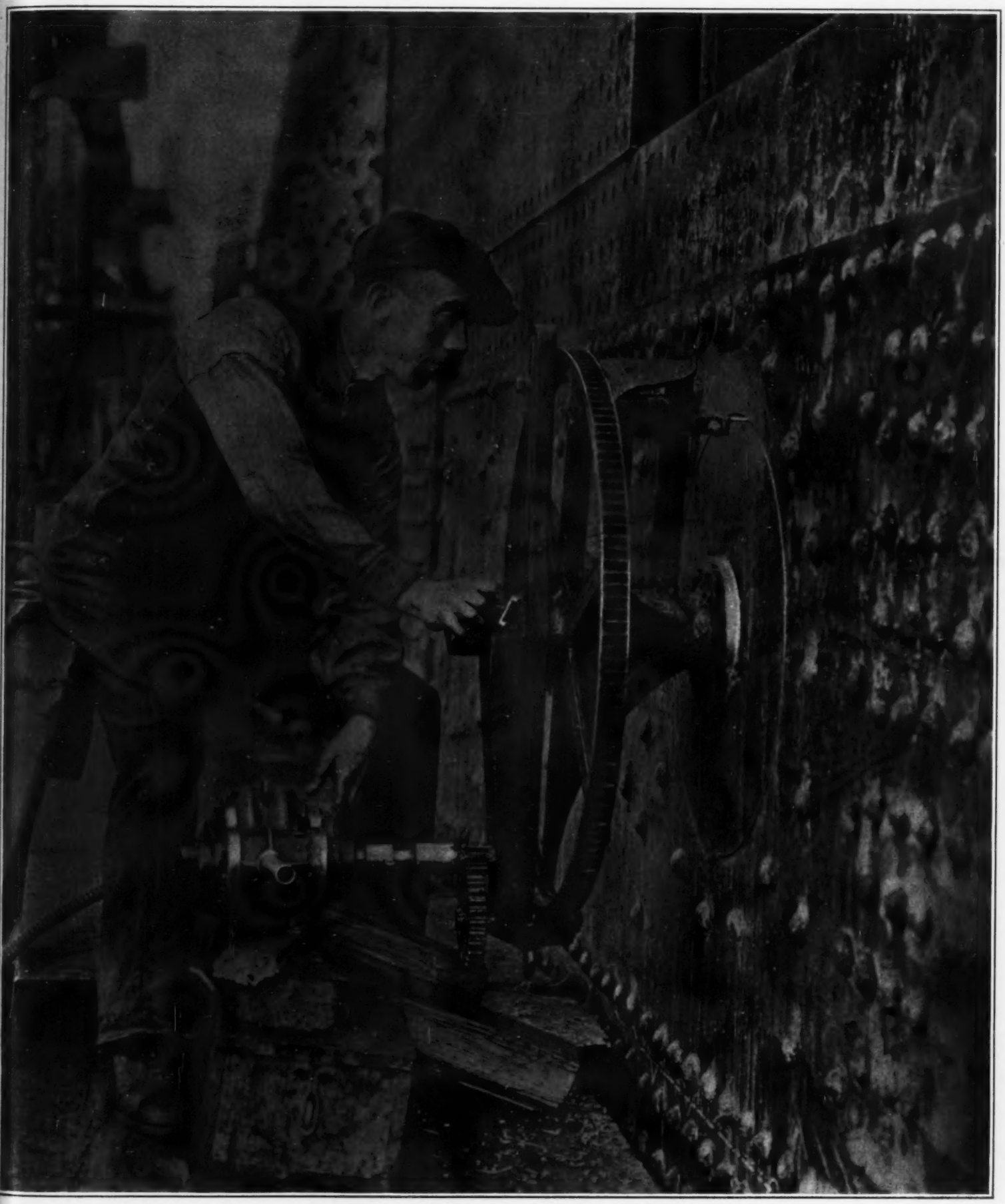


Cutting the Side Lights With the Pneumatic Machine.

THE LATEST AND LARGEST MEMBER OF THE ANGLO-AMERICAN FLEET.—[See page 264.]

The Photo-Chemistry of the Future*

A Branch of the Science Which Seems Destined to Rise to Great Importance

By Prof. Giacomo Ciamician

MODERN civilization is the daughter of coal, for this offers to mankind the solar energy in its most concentrated form; that is, in a form in which it has been accumulated in a long series of centuries. Modern man uses it with increasing eagerness and thoughtless prodigality for the conquest of the world and, like the mythical gold of the Rhine, coal is to-day the greatest source of energy and wealth.

The earth still holds enormous quantities of it, but coal is not inexhaustible. The problem of the future begins to interest us, and a proof of this may be seen in the fact that the subject was treated last year almost at the same time by Sir William Ramsay before the British Association for the Advancement of Science at Portsmouth and by Prof. Carl Engler before the Versammlung deutscher Naturforscher und Aerzte at Karlsruhe. According to the calculations of Prof. Engler Europe possesses to-day about 700 billion tons of coal and America about as much; to this must be added the coal of the unknown parts of Asia. The supply is enormous but, with increasing consumption, the mining of coal becomes more expensive on account of the greater depth to which it is necessary to go. It must therefore be remembered that in some regions the deposits of coal may become practically useless long before their exhaustion.

Is *fossil* solar energy the only one that may be used in modern life and civilization? That is the question.

Sir William Ramsay has made a very careful study of the problem from the English point of view. He has considered the various sources of energy, such as the tides, the internal heat of the earth, the heat of the sun, water-power, the forests and even atomic disintegration, and has come to the conclusion that none can be practically used in England on account of her special contour and climate.

Though the internal energy of the earth may produce terrible disasters through volcanic eruptions and earthquakes, it can hardly be used by man. The energy derived from the rotation of the earth (tides) can hardly be counted upon on account of the enormous quantities of water that would have to be handled. Atomic disintegration has recently been treated in a brilliant lecture by Frederick Soddy, with special reference to the enormous energy changes which are involved. If man ever succeeds in availing himself of the internal energy of the atoms, his power will surpass by far the limits assigned to it to-day. At present he is limited to the use of solar energy. Let us see, however, whether the *actual* energy may not supplant that stored up in fossil fuel. Assuming that the solar constant is three small calories a minute per square centimeter, that is, thirty large calories a minute per square meter or about 1,800 large calories an hour, we may compare this quantity of heat with that produced by the complete combustion of a kilogramme of coal, which is 8,000 calories. Assuming for the tropics a day of only six hours sunshine we should have, for the day, an amount of heat equivalent to that furnished by 1.35 kilogrammes of coal, or one kilogramme in round numbers. For a square kilometer we should have a quantity of heat equivalent to that produced by the complete combustion of 1,000 tons of coal. A surface of only 10,000 square kilometers receives in a year, calculating a day of only six hours, a quantity of heat that corresponds to that produced by the burning of 3,650 million tons of coal, in round numbers three billion tons. The quantity of coal produced annually (1909) in the mines of Europe and America is calculated at about 925 million tons and, adding to this 175 million tons of lignite, we reach 1,100 million tons, or a little over one billion. Even making allowances for the absorption of heat on the part of the atmosphere and for other circumstances, we see that the solar energy that reaches a small tropical country, say of the size of Latium, is equal annually to the energy produced by the entire amount of coal mined in the world! The desert of Sahara with its six million square kilometers receives daily solar energy equivalent to six billion tons of coal!

This enormous quantity of energy that the earth receives from the sun, in comparison with which the part which has been stored up by the plants in the geological periods is almost negligible, is largely wasted. It is utilized in waterfalls (white coal) and by plants. Several times its utilization in a direct form through mirrors has been tried, and now some very promising experiments are being made in Egypt and in Peru; but this side of the problem is beyond my power to discuss and I do not propose to treat it on this occasion.

The energy produced by water-power during the period of one year is equal to that produced by 70 billion tons of coal, according to the data given in Prof. Engler's lecture. It is, however, very small, as might be expected, in comparison with the total energy that the sun sends to the earth every year. Let us now see what quantity of solar energy is stored by the plants: on the total surface of the various continents, which is 128 million square kilometers, there is a yearly production of 32 billion tons of vegetable matter, which, if burnt, would give the quantity of heat that corresponds to the total combustion of 18 billion tons of coal. It is not much, but even this is 17 times as much as the total present production of coal and of lignite.

I.

Now let us consider the first part of our subject. Is it possible or, rather, is it conceivable that this production of organic matter may be increased in general and intensified in special places, and that the cultivation of plants may be so regulated as to make them produce abundantly such substances as can become sources of energy or be otherwise useful to civilization? I believe that this is possible. It is not proposed to replace coal by organic substances produced by plants; but it is conceivable that this organic matter may be utilized more satisfactorily than is now the case.

It has frequently been said, even by persons of authority, that some day the transformation of coal into bread may become not only possible but economically desirable. According to these people the ideal of the future should be to produce through synthesis from coal all substances necessary for the alimentation of man: such substances as starch, sugar and fat, also proteins and perhaps cellulose; in other words to abolish agriculture altogether and to transform the world into a garden of useless flowers. Never was a greater fallacy thought or expressed: the real problem is just the reverse of this. My friend Prof. Angeli wisely called to my attention that, while the externals of life have been changed greatly by the progress of industry so as to use all our technical knowledge to increase our comfort, the quality and quantity of human alimentation have hardly changed at all; nay, a new science has come into existence (bromatology) to see that no artificial product of industry enters harmfully into our alimentation. At the time of Napoleon III. an attempt was made to substitute gelatine for meat; but it was seen very soon, and now the reason for it is known by all, that this substitute could not be sufficient to maintain life. With the relatively small reserves of coal that the past geological epoch have stored for us, it will never be desirable to produce from coal what nature generously offers us through solar energy. It is on the other hand a work worthy of praise to attempt to make plants produce the fundamental substances in larger quantity. Modern agriculture tries to do this by intensive cultivation; but it is also desirable to make the plants store up solar energy and transform it into mechanical energy.

A well-known instance of this occurred when the development of the daily press in all civilized countries made it imperative to provide wood pulp in a sufficient quantity and at low prices. Trees better adapted to the purpose were soon found and they were those which, on account of their rapid growth, could furnish the necessary cellulose sooner. For the problem we are now considering the quality of the plants is of secondary importance; they may be herbs or trees; they may grow in swamps or dry places, on the sea coast or even in the sea; the essential point is that they grow fast or that their growth may be intensified. It would be like realizing the desire of Faust:

"Und Bäume die sich täglich neu begrünen!"

Mephistopheles did not consider a similar task impossible:

"Ein solcher Auftrag schreckt mich nicht,
Mit solchen Schätzen kann ich dienen."

Should we consider the task impossible, naturally in a more limited sphere, after so many centuries of culture? I do not believe so. The above estimate of the total production of organic matter over all the solid surface of the earth, that is, of 32 billion tons a year, has for its basis the old calculation of Liebig of 2.5 tons per hectare. This may be considered even to-day the average production for all the earth. According to A. Mayer, through intensified culture the production may be increased to 10 tons per hectare, and in tropical climates it may reach 15 tons. On a square kilometer it would be 1,500 tons, corresponding to 840 tons of coal, while the solar energy received in a year by a square kilometer would be equivalent to about 300,000 tons of coal, the part of the total energy stored up by the plants being about 1/300. A great deal remains to be done, but if we consider that since Liebig, largely by adopting the methods proposed by him, the production has been at least quadrupled, we may hope to do much more in the future especially if we are spurred on by necessity or even by convenience.

By increasing the concentration of carbon dioxide up to an optimum value (1 to 10 per cent, according to Kreusler) and by using catalyzers, it seems quite possible that the production of organic matter may be largely increased, making use, of course, of suitable mineral fertilizers and selecting localities adapted to the purpose owing to the climate or the condition of the soil. The harvest, dried by the sun, ought to be converted, in the most economical way, entirely into gaseous fuel, taking care during this operation to fix the ammonia (by the Mond process, for instance) which should be returned to the soil as nitrogenous fertilizer together with all the mineral substances contained in the ashes. We should thus get a complete cycle for the inorganic fertilizing substances, the only waste being that common to all industrial processes. The gas so obtained should be burnt entirely on the spot in gas engines and the mechanical energy thus generated should be transmitted elsewhere or utilized in any way that seems advisable. We need not go into details. The carbon dioxide, resulting from the combustion, should not be wasted but should be returned to the fields. Thus the solar energy, obtained by rational methods of cultivation, might furnish low-priced mechanical energy, perhaps better than through the systems based on mirrors, because the plants would be the accumulators of the energy received by the earth.

But the problem of the utilization of plants in competition with coal has another and more interesting side. First of all we must remember the industries which have their basis in agriculture: the cotton and other textile industries, the starch industry, the production of alcohol and of all fats, the distillation of wood, the extraction of sugar, the production of tanning substances and other minor industries. All these industries are susceptible of improvement not only by the introduction of more advantageous technical devices in the treatment of the raw materials but also by a largely increased production of the raw materials. Let us think for an example of the progress made in the production of beet sugar.

The plants are unsurpassed masters of, or marvelous workshops for, photochemical synthesis of the fundamental substances, building up from carbon dioxide with the help of solar energy. They also produce the so-called secondary substances with the greatest ease. These latter are usually found in the plants in small quantity and are of value for special reasons. The alkaloids, glucosides, essences, camphor, rubber, coloring substances and others are of even greater interest to the public than the fundamental substances on account of their high commercial value. In this field a battle is raging between chemical industry and nature, a battle which does honor to human genius. Up to now the products prepared from coal tar have almost always been triumphant. I do not need to remind you of the various victories; but it is possible that these may prove to have been Pyrrhic victories. A great authority on organic industries considered recently what would happen in case, for any reason, there were a rapid increase in the price of coal tar and consequently of the substances contained in it. He pointed out the inevitable effect of this on the coal tar industries. We all remember with admiration the story of the great difficulties that had to be met in the choice of the raw material for the production of indigo. It was necessary finally to use naphthalene because toluene could not be obtained in sufficient quantity. But it is not merely through a rise in the price of the raw materials that an industry may suffer; it may be brought to a standstill by a diminished interest and activity in a certain field of scientific study. It has been thoroughly established that modern industry is affiliated very intimately with pure science; the progress of one determines necessarily that of the other. Now the chemistry of benzene and its derivatives does not constitute the favorite field of research as it did during the second half of the last century. The center of interest is now to be found in the matters and problems connected with biology. Modern interest is concentrated on the study of the organic chemistry of organisms. This new direction in the field of pure science is bound to have its effect

* General lecture before the International Congress of Applied Chemistry, 1912.

on the technical world and to mark out new paths for the industries to follow in the future.

It is a fact that lately several organic industries have been successfully developed, outside of the field of benzene and coal tar. There are flourishing industries in essences and perfumes and in some alkaloids, like coca. In these industries products, which plants produce in relatively large amounts, are converted into products of higher commercial value. For instance, everybody knows that essence of violet is now made from citral contained in lemon oil. This is a line along which we ought to follow because we are certain of making progress. It is to be hoped that in the future we may obtain rubber commercially in some such way.

The question has still another side, which I believe deserves your attention; it concerns certain experiments recently made by myself together with Prof. Ravenna at Bologna. It is not because we have arrived at any practical results that I refer to these experiments; but because they show definitely that we can modify to a certain extent the chemical processes that take place during the life of the plants. In a series of experiments made in an effort to determine the physiological function of the glucosides, we have succeeded in obtaining them from plants that usually do not produce them. We have been able, through suitable inoculations, to force maize to synthesize salicine. More recently, while studying the function of the alkaloids in the plants, we have succeeded in modifying the production of nicotine in the tobacco plant, so as to obtain a large increase or a decrease in the quantity of this alkaloid. This is only a beginning, but does it not seem to you that, with well-adapted systems of cultivation and timely intervention, we may succeed in causing plants to produce, in quantities much larger than the normal ones, the substances which are useful to our modern life and which we now obtain with great difficulty and low yield from coal tar? There is no danger at all of using for industrial purposes land which should be devoted to raising foodstuffs. An approximate calculation shows that on the earth there is plenty of land for both purposes, especially when the various cultivations are properly intensified and rationally adapted to the conditions of the soil and the climate. This development is the real problem of the future.

II.

Technical organic industry may yet expect great help from photochemistry understood in the sense above expressed and the competition between this and the chemistry of coal tar will be a great incentive for new progress. It is also true that human genius will always tend to proceed along lines selected by itself, and there is no question but that the great development in the coal tar industry has been due in part to this splendid spirit of independence. It may be asked whether there are not other methods of production which may rival the photochemical processes of the plants. The answer will be given by the future development of photochemistry as applied to the industries and on this I have a few ideas to express. The photochemical processes have not had so far any extensive practical application outside of the field of photography. From its very beginning photography has aroused a great deal of interest; it was taken up technically and, as usually happens in similar cases, it had a rapid and brilliant success. But notwithstanding the many applications photography represents only a small part of photochemistry. So far, photochemistry has only been developed to a very slight extent, perhaps because chemists have been attracted by problems which seemed more urgent. So it happens that while thermochemistry and electrochemistry have already reached a high degree of development, photochemistry is still in its infancy. Now, however, we notice a certain awakening due to a series of studies concerning general problems and special processes, especially in the organic field, in which my friend Dr. Paul Silber and myself have taken an active part. Two recent publications, one by Plotnikow and the other by Benrath, bear witness to this. But much remains to be done both in theoretical and general photochemistry as well as in the special branches.

The photochemical reactions follow the fundamental laws of affinity, but have a special character. They are especially notable for the small temperature coefficient and are, however, comparable—a fact which is not without technical importance, to the reactions which take place at very high temperatures. According to a brilliant idea of Plotnikow, luminous radiations produce a different ionization from that due to electrolytic dissociation; the separation of an ion requires a quantity of light which is determined by the theory of Planck and Einstein. The question is therefore related to the most recent and profound speculations of mathematical physics.

For our purposes the fundamental problem from the technical point of view is how to fix the solar energy through suitable photochemical reactions. To do this it would be sufficient to be able to imitate the assimilating processes of plants. As is well known, plants transform the carbon dioxide of the atmosphere into starch, setting free oxygen. They reverse the ordinary process of combustion. It has always seemed probable that formaldehyde was the first product of the assimilation; and Curtius has at last demonstrated its presence in the leaves of the beech trees. The artificial reproduction of a similar process by means of ultraviolet rays has already been obtained by D. Berthelot. With convenient modifications could not this now actually be done on the tropical highlands? Yet the true solution consists in utilizing the radiations that pass through the entire atmosphere and reach the surface of the earth in large amounts. That a way of accomplishing this exists is proved by the plants themselves. By using suitable catalyzers, it should be possible to transform the mixture of water and carbon dioxide into oxygen and methane, or to cause other endo-energetic processes. The desert regions of the tropics, where the conditions of the soil and of the climate make it impossible to grow any ordinary crops, would be made to utilize the solar energy which they receive in so large a measure all the year, that the energy derived from them would be equal to that of billions of tons of coal.

Besides this process, which would give new value to the waste products of combustion, several others are known, which are caused by ultraviolet radiations and which might eventually take place under the influence of ordinary radiations, provided suitable sensitizers were discovered. The synthesis of ozone, of sulphur trioxide, of ammonia, of the oxides of nitrogen, as well as many other syntheses, might become the object of industrial photochemical processes.

It is conceivable that we might make photoelectrical batteries or batteries based on photochemical processes, as, for instance, in the experiments of C. Winther.

Passing to the field of organic chemistry, the reactions caused by light are so many that it should not be difficult to find some which are of practical value. The action of light is especially favorable to processes of reciprocal oxidation and reduction which give rise to or are associated with phenomena of condensation. Since the common condensation is that of the aldolic type there is much hope for the future, the aldolic condensation being the fundamental reaction of organic synthesis.

To get an idea of the variety of photochemical reactions we may confine ourselves to a systematic study of the ketones and alcohols. In ordinary organic chemistry the reactions often take place in some definite way; but the photochemical reactions often furnish surprises and proceed along quite different lines. From the very first experiments we knew that benzophenone did not form addition products with ethyl alcohol, but was converted into pinacone at the expense of the alcohol, which was oxidized to aldehyde. Proceeding with the study of aliphatic ketones, similar to acetone, we have this year discovered a remarkable fact. Methylethylketone condenses with itself and forms the paradiketone, reducing itself at the same time to secondary butyl alcohol:

$$\begin{array}{cccc} CH_3 & CH_3 & CH_2 & CH_3 \\ | & | & | & | \\ 3CH_2 & CH_2 & CH & CH \\ | & = | & + | & | \\ CO & CHOH & CO & CO \\ | & | & | & | \\ CH_3 & CH_3 & CH_3 & CH_3 \end{array}$$

Of course the synthesis of diketones by light could not be an isolated reaction; we had previously noticed the formation of diacetyl: acetonylacetone is found, as we now know, among the products of acetone in solution in ethyl alcohol and it is also possible that the metadiketones, such as acetylacetone for instance, may be prepared photochemically. These reactions have a special importance on account of the special character of the diketones and their tendency to change in all sorts of ways. From them derivatives of benzene can be obtained as well as of pyrrazol and isoxazol, of quinoline, of furfurol, of thiophene and of pyrrol. In regard to this last change I wish to remind you that tetramethylpyrrol corresponds to the paradiketone previously referred to. If I dare to be reckless, as you may see I am at this moment, contrary to my custom, but perhaps urged thereto unconsciously by the American genius which heeds no obstacles, I may refer to the relations between the polysubstituted pyrrols with alcohol radicals and chlorophyll, and I may see in these reactions the possibility of the synthesis of this fundamental substance by means of an artificial photochemical process. Its formation in plants, like its function, is due to a photochemical process; we do not know, however, whether and in what measure light enters into all the synthetic plant reactions, from which originate the various substances which we find in plants. The research should proceed together in the two fields; phytochemistry and photochemistry will be of great help one to another. Industrially this co-operation might have a great future: the raw materials obtained from the plants might be refined through artificial photochemical processes.

Lately we have been interested intensely by the changes that some substances of the group of the terpenes and of the camphors undergo when exposed to light, especially through hydrolytic processes. So far, indeed, our experiments have taught us that light can spoil rather than improve essences. The cycloketones, for instance, are hydrolyzed and give the corresponding fatty acids.

In photochemistry, however, one reaction does not exclude the other; the reactions may be reversed as some recent experiments with ultraviolet rays demonstrate; for the ultraviolet rays sometimes reverse reactions caused by less refrangible radiations. It is important to find suitable sensitizers and catalyzers.

I do not believe, however, that the industries should wait any longer before taking advantage of the chemical effects produced by light. The polymerizations, the isomeric changes, the reductions and oxidations with organic and inorganic substances, and the autoxidations which light causes so easily should already find profitable applications in some industries if researches were carried out carefully with this in mind. The action of light on nitric and nitrosilicic compounds, as we know it from experience, is one that ought to be utilized profitably. Our own transformation of orthonitrobenzoic aldehyde into nitrosobenzoic acid has recently been studied by various chemists, and has been made use of by Pfeiffer, who prepared a nitrophenylisatogen from chlorodinitrostilbene. This reminds us of the not less known transformation of benzylidene orthonitroacetophenone into indigo by Engler and Dorant and makes us foresee a new field in the photochemical production of artificial colors and dyestuffs. The scope of studies on this subject ought not to be limited to preserving colors from fading, bleaching and all changes produced by light. The photochemistry of colors and dye-stuffs ought to furnish new methods of preparation and of dyeing. Very encouraging experiments have already been made with diazoic compounds and mention should be made of the recent observation of Baudisch that α-nitrosonaphthylhydroxylamine is changed on the fiber to azoxynaphthalene when exposed to light. The autoxidation of leuco compounds by light is an old practice of which the ancients availed themselves for preparing purple; now the process is explained, thanks to the familiar researches of Friedländer, but it is clear that a great deal remains to be learned in this field.

Phototropic substances, which often assume very intense colors in the light, and afterward return in the darkness to their primitive color, might be used very effectively. Such substances might well attract the attention of fashion rather than fluorescent materials which give the impression of changing colors. The dress of a lady, so prepared, would change its color according to the intensity of light. Passing from darkness to light the colors would brighten up, thus conforming automatically to the environment: the last word of fashion for the future.

Solar energy is not evenly distributed over the surface of the earth; there are privileged regions, and others that are less favored by the climate. The former ones would be the prosperous ones if we should become able to utilize the energy of the sun in the way which I have described. The tropical countries would thus be conquered by civilization, which would in this manner return to its birthplace. Even now the strongest nations rival each other in the conquest of the lands of the sun, as though unconsciously foreseeing the future.

Where vegetation is rich, photochemistry may be left to the plants and by rational cultivation, as I have already explained, solar radiation may be used for industrial purposes. In the desert regions, unadapted to any kind of cultivation, photochemistry will artificially put their solar energy to practical uses.

On the arid lands there will spring up industrial colonies without smoke and without smokestacks; forests of glass tubes will extend over the plains and glass buildings will rise everywhere; inside of these will take place the photochemical processes that hitherto have been the guarded secret of the plants, but that will have been mastered by human industry which will know how to make them bear even more abundant fruit than nature, for nature is not in a hurry and mankind is. And if in a distant future the supply of coal becomes completely exhausted, civilization will not be checked by that, for life and civilization will continue as long as the sun shines! If our black and nervous civilization, based on coal, shall be followed by a quieter civilization based on the utilization of solar energy, that will not be harmful to progress and to human happiness.

The photochemistry of the future should not, however, be postponed to such distant times; I believe that industry will do well in using from this very day all the energies that nature puts at its disposal. So far, human civilization has made use almost exclusively of fossil solar energy. Would it not be advantageous to make better use of radiant energy?

The Size of the Finest Organic Structures*

How Magnitudes Beyond the Resolving Power of Our Best Microscopes Are Estimated

By Prof. Dr. W. Stempell

MINUTE anatomy has provided a fascinating subject for biological study ever since the introduction of the microscope. The resolving power of the microscope, however, cannot by any means whatever be increased beyond a certain limit set by the very nature of light. For this reason actual observations have at times been supplemented by more or less speculative reasoning based on the hypothetical size of the protein molecule. In this way it has been argued that organisms containing several thousand such protein molecules must measure at least 0.05 to 0.1μ (1μ = 1 micromillimeter = 1/1,000 millimeter = about 1/25,000 inch). This would place them among magnitudes not far removed from those just discernible with the microscope, whose extreme limit of resolving power may be put at 0.2μ, say.[1]

But all calculations of this kind labor under the disadvantage, that they are based on a hypothetical figure —the minimum size of a protein molecule—which is rather arbitrarily fixed, as we have at best only a very uncertain knowledge of it. It would be much more satisfactory if we could use for the basis of our calculation some actually measured structure.

As regards the resolving power of the microscope, if e is the distance apart of two features which the microscope can just separate, and if λ is the wave-length of the light employed, and if a is the numerical aperture of the objective, then e is connected with λ and a by the relation.

$$e = \frac{\lambda}{a}$$

With ordinary light and a numerical aperture of 1.30 we have $e = 0.42\mu$. With oblique illumination, in which case

$$e = \frac{\lambda}{2a}$$

the value of e is further reduced to 0.21μ. With a numerical aperture of 1.40 this can be brought down to 0.19μ. Further reduction can only be secured by using ultra-violet light of short wave-lengths, in which case of course direct vision has to be abandoned and replaced by photographic observation. With oblique illumination and cadmium light of wave-length $\lambda = 275\mu\mu$, the distance between two points just separated can finally be reduced to about 0.11μ. This then represents practically the extreme limit of resolving power of the modern microscope.

An object particularly well adapted to serve as a standard of measurement is the spore of microsporidia, an excessively minute animal parasite. These spores are egg-shaped and contain a coiled up thread which, under certain conditions, is projected outward, being bodily turned inside out in the process. (See Fig. 1.) In the species known as *Nosema bombycis Nägeli*, the germ of the silk worm disease, this thread, when protruded, has a length of 34μ and it has been definitely determined by microphotography in ultra-violet light, that the thread, when coiled up within the spore, has

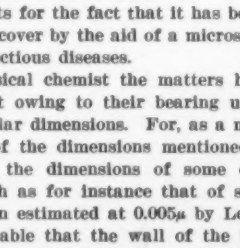


Fig. 2.—A Number of Spores of Nosema Photographed by Ultra-violet Light.

ten windings, its diameter being just about 1μ (1/25,000 of an inch). This fact can be checked directly from the photograph represented in the accompanying illustration, Fig. 2. In that photograph the space occupied by the spiral thread measures 8 by 4 millimeters, and, as the object is magnified 3,600 times, this corresponds to an actual dimension of 2 by 1μ. It shows about 19 alternate black and white lines, corresponding to the 10 coils of the spiral and the spaces between them. Each of these measures about 0.4 millimeter in the photograph, or 0.1μ in the object. The result of this measurement is further substantiated by the computation of the thickness of the thread from its length when projected to its full extent, and the space occupied by it in the interior of the spore. The entire spore is 4μ long and 2μ thick. The thickness of its envelope is 0.5μ. Hence the space within the envelope measures 3μ at its greatest and 1μ at its smallest diameter. About one third of this space is occupied by a mass of protoplasm (see Fig. 1, the darkly shaded portion), and there is thus left for the coiled up thread at most a cylindrical space 2μ long and 1μ in diameter. By measurement of an extended thread it is found to be 34μ long. From the space available in the interior of the spore it follows that the diameter of each coil can be at most 1μ, hence its circumference at most is 3μ, and therefore there can be at most ten windings in each coil.

Now this thread is actually a tube, which is turned inside out in the process of extrusion. Its wall, therefore, even if we allow nothing at all for the space within the tube, can at most have a thickness of 0.05μ. In other species it can be shown that the wall of the thread can be no thicker than 0.008μ.

It will therefore be seen that among organisms there are structures of dimensions much smaller than have hitherto been suspected by bacteriologists. The demonstration of this is of considerable interest both to the biologist and to the physical chemist. The biological interest is derived from the fact that it is rendered extremely probable that organisms exist of such small size that we, with our most refined optical means, are not in a position to detect them.[2]

This accounts for the fact that it has been impossible hitherto to discover by the aid of a microscope the germ of certain infectious diseases.

To the physical chemist the matters here discussed are of interest owing to their bearing upon the question of molecular dimensions. For, as a matter of fact, the smallest of the dimensions mentioned above come very near to the dimensions of some of the larger molecules, such as for instance that of soluble starch, which has been estimated at 0.005μ by Lobry Debruyn. It is not probable that the wall of the thread of the Nosema consists of a single layer of molecules; there are no doubt at least three such layers. This would give for the protein molecules a diameter of 0.0025μ. Assuming a specific gravity of unity, this would give for the molecular weight of protein a value of 500,000. This represents a maximum. In point of fact there are probably more than three layers of molecules, and moreover the structures here discussed are probably not the smallest which occur in nature. Therefore, the actual size of the protein molecule is probably considerably smaller than the figure indicated, i. e., 500,000.

* Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from *Prometheus*.

[1] Cf. Benecke, *Bau und Leben der Bakterien*, 1912, pp. 44, 45. See also SCIENTIFIC AMERICAN SUPPLEMENT, March 15th, 1913, p. 162.

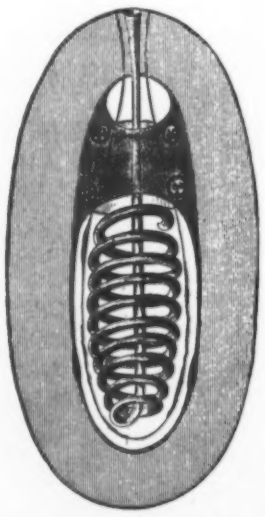


Fig. 1.—Diagram of the Internal Structure of a Spore of Nosema (Magnified 20,000 Times).

The darkly shaded portion at the top is a mass of protoplasm with four nuclei. Through the center of this passes the thread or flagellum, which is coiled within the hollow spore, but can be projected outward, when it turns bodily inside out.

[2] Compare Prof. Behchold's article on "Ultra-filtration" in the SCIENTIFIC AMERICAN SUPPLEMENT for March 14th, 1908, p. 166.

An Experiment for Showing Lines of Force in an Electrostatic Field

EVERYONE is familiar with the method of mapping a magnetic field of force by the aid of iron filings, which may, if desired, be made permanent by receiving the filings upon a suitable adhesive support, such as wax softened by heat.

More difficulty is experienced in mapping an electric field of force, but the following method, described by B. M. Neville in *Nature*, provides a simple means for the purpose.

The method consists simply in allowing a scrap of cotton-wool to fall between the knobs of a Wimshurst machine, or among any conductors connected with them. As soon as the bit of fluff touches one of the conductors it moves off rapidly along a line of force. If the other conductor is oppositely charged the fluff will strike it, and again be repelled, usually in a slightly different direction, thus traversing a different line of force, and so on.

The scrap of charged fluff moves so rapidly under the electric forces that, owing to the persistence of vision, the shape of its path is very evident, and, owing to its lightness and the relatively great resistance offered by the air to its motion, its path approximates very closely indeed to the line of force.

Electric Drill for Watch Makers

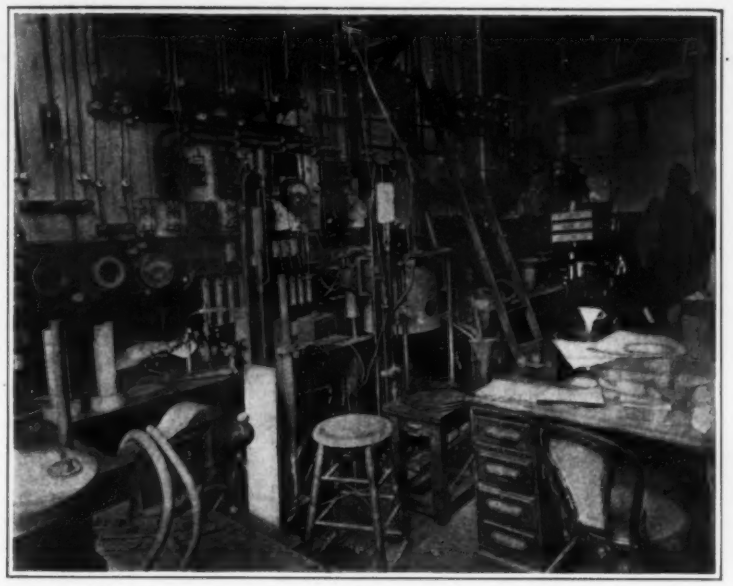
THE mechanism shown in our illustration comprises a small electric motor and a pulley attached to the end of a bracket. The power is transmitted from the motor to the pulley and from the pulley to the drill spindle by means of a cord belt. By shifting a small lever the cord between the pulley and the drill holder can be slackened, whereby the latter is immediately brought to rest. The motor and pulley then continue to run empty and are ready at any instant to actuate the drill with the requisite speed as soon as the arresting lever is released.

The stem of the bracket which carries the pulley is constructed in telescopic fashion so that the tension of the cord can be adjusted at will. This is not only convenient in ordinary working, but also makes it unnecessary to determine with great exactness the length of the cord when renewing it, since the bracket can be adjusted to fit the cord.

The whole installation can be attached in a few minutes to the working table, and thus forms a portable and very handy outfit. The motor is connected to the electric leads in the usual manner by means of flexible cord. The only accessory apparatus required is a contact breaker. The motor is constructed for all tensions up to 380 volts.

The Electric Watch Maker's Drill Attached to the Work Table.

A Room in Which Investigations Regarding Hysteresis and Magnetic Permeability of Iron are now Being Carried on.



Experiments Relating to the Construction of Mercury Arc Rectifiers are Made in This Section of the Research Laboratory.

A Great Research Laboratory of Applied Electricity*

Its Development and Nature of the Work Carried On There

By Christian Dantsizen

On January 1st, 1901, the General Electric Company engaged Dr. W. R. Whitney, then a professor of chemistry in the Massachusetts Institute of Technology, to organize a department of chemical and physical research. The investigations to be undertaken were, of course, to be connected directly with the field of electrical engineering. Dr. Steinmetz, who has been connected with the company since 1893, was, without doubt, one who at that time urged most strongly such an organization. During the years 1898, 1899, and 1900, he himself had conducted a private research laboratory in Schenectady, where he studied chiefly resistance materials, electric furnaces, and the production of metallic carbides. He had also commenced work in the field of electric lighting, particularly in the direction of luminous arcs and vapors. On the night of January 20th, 1901, Dr. Steinmetz's laboratory burned down, and during the next few days all the apparatus which was saved was removed to the company's new laboratory.

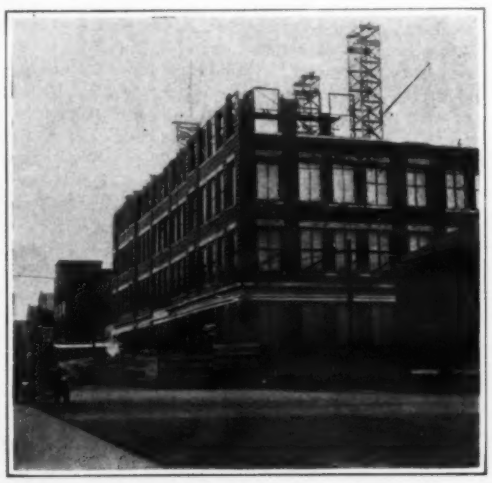
At first Dr. Whitney gave but half of his time to directing the work, arriving every Thursday morning and returning to Boston Saturday night. During the summer vacation of the Institute of Technology he was able to give all his time to the work at Schenectady, and in 1904 the work of the Research Laboratory had assumed such proportions that he gave up teaching and moved to the electric city. In June, 1901, he obtained two men from the graduating class of the Massachusetts Institute of Technology, and a month later he had increased his force to five.

The first laboratory was located in a small room 50 feet by 100 feet, in one of the older buildings of the company. In September, 1901, there were twelve men crowded into this little place, but a month later the congestion was relieved when the entire equipment was removed to another building, where ten times more floor space was secured. By April, 1904, the research force, still increasing, reached thirty-five men in number, so that it was again necessary to change the location of the laboratory. This time it moved to its present quarters, previously the first two floors of an office building. In all, there are in this place about forty rooms, each about 20 feet square, given over to specialized lines of research. Each apartment is well lighted by windows and incandescent lamps, and is piped for water, illuminating gas, and hydrogen. Some of the rooms are piped for nitrogen, oxygen, steam, vacuum, and compressed air. As an example of the quantities of gas used, it might be mentioned that fifteen thousand cubic feet of hydrogen, under six inches of water pressure, can be delivered every day. The electric wiring in the laboratory is very complete, in that voltages varying from zero is 6,000, currents up to 200 amperes, and power up to 150 kilowatts, can be obtained in each room, and that for special work higher voltages and currents can be secured. The generator room has for its source of power direct current, supplied at 250 volts, and this direct current is converted, by about fifteen motor generator sets, varying from 5 horse-power to 200 horse-power, to direct current of different voltages and alternating current of various voltages and frequencies. There is also a well equipped machine shop and a well stocked chemical supply room.

The laboratory library has about 50 per cent more volumes than the library in the Salisbury Building of the Worcester Polytechnic Institute. Sixty-four periodicals are taken. These come under the heads of General Science, General Chemistry, Physical Chemistry, Technical Chemistry, Electro-chemistry, Physics, and Metallurgy. The General Electric Company also has a main library in one of its other buildings. Here books and periodicals referring to mechanics and electricity may be obtained.

Notwithstanding the fact that the laboratory is so well equipped, it can, moreover, come into direct touch with any of the other departments of the company, and can make use of the equipments of these departments.

Even during the short period in which the laboratory was confined to a single room, important inventions were under way. During the second period of its life, that is, from October, 1901, to April, 1904, the investigations undertaken included researches on electric furnaces and their products, organic and inorganic insulating materials, metallurgical operations, and electric lighting by means of incandescent lamps, luminous arcs, and vapors. Particular stress was placed on efficiency and the spectral characteristics of lighting. During this same period there were produced the so-called metallized carbon filament, the mercury arc rectifier, and the magnetite arc lamp.



The New Electrical Research Laboratory Building Now Under Construction.

In the present building, that is, during the third period of the development of the laboratory, the metal tungsten was first produced in such a high state of purity that it could be drawn into wire stronger than the strongest steel, and finer than any metal had before been drawn. Drawn tungsten incandescent lamp filaments have, without doubt, constituted the greatest step forward in electric lighting during the past decade. As a result of this metallurgical knowledge, the tungsten X-ray target and the tungsten electric make-and-break contact were invented, and have proved to be better than the similar platinum articles.

During the last ten years electric furnaces of nearly every type and capacity up to 1,000 kilowatts have been studied. The Arsem vacuum furnace and the tungsten resistance furnace, both capable of maintaining a temperature of 3,000 deg. Cent., are the products of the Research Laboratory. Naturally, with all these furnaces on hand, hundreds of alloys, binary and tertiary, have been compounded and their physical and chemical properties determined. The magnetic properties of iron and its alloys have been investigated, with the result that, during the last eight years, eddy current and hysteresis losses in transformer steels have been very greatly reduced.

At present, a force of over one hundred people is maintained in the Research Laboratory. The staff consists of Dr. W. R. Whitney, director; Dr. W. D. Coolidge, assistant director; and about fifty college men. Two of these men are graduates of the Worcester Polytechnic Institute. Some of the investigations now going on are the preparation and study of alloy systems with such purposes as obtaining high electrical resistivity, resistance to corrosion, and definite coefficients of thermal expansion, the replacement of platinum by such metals as tungsten and molybdenum, the production of high temperature resistance furnaces, the preparation of organic and inorganic insulators, and the study of electrical methods of illumination by means of incandescent filaments, arcs, or gases.

At a cost of about $300,000, the company is now erecting a seven-story red brick building in which the Research Laboratory and the Standardizing Laboratory will be brought under the same roof. This building will contain, among other improvements, an assembly room, built in regular lecture room style, where colloquia of the members of the research staff will be held to discuss matters under investigation and to listen to speakers from the various colleges, universities, or from another company. At the present time such colloquia are held every Saturday morning, from 11 to 12:30, in the library of the laboratory.

Researches in the laboratory of the General Electric Company, as well as in other commercial laboratories, differ somewhat from researches carried on in universities. This difference lies not only in the fact that the former must be money-making propositions, while the latter have for their main object the advancement of general knowledge, but also in the fact that the industrial researches are, for the most part, of

* Reproduced from the *Journal* of the Worcester Polytechnic Institute.

the convergent variety, while the university investigations are chiefly of the divergent type. As a rule, the university man starts his investigation from some one known point in the universe of science, and branches out, making a series of interdependent discoveries. An organic chemist, for example, may start from a single compound, and, by the time he has subjected this compound to various organic processes, such as hydrolyzing, sulphonating, brominating, attaching rings and side chains, etc., a volume of data has been gathered. Such a research is certainly divergent, or expanding.

In a commercial research laboratory, on the other hand, the object of the research is not to start from one point and create a field, but to start from a field to locate one point, to find one or more ways of bringing about one result, the development of a process or article for which there has been great need, or which will have immediate practical value as soon as produced. In this case the theories and experiments are directed from as many points in the before-mentioned universe of science as all those interested in the problem can possibly handle. It is quite possible that ninety-nine out of the hundred of these subsidiary investigations have to be abandoned because later it is found that they are not directed toward the object of the research, and that the hundredth, the correct line of attack, is found by elimination. This, then, is convergent, or contracting, research. Yet it cannot be assumed that there is but one solution to any problem in convergent research, for, in fact, it does not seem reasonable that, when a certain long-sought phenomenon is discovered in a heretofore unknown field of science, the path by which it is first reached is the only path, or the most direct one. Very often the solution may be reached by a number of totally different ways, yet it is true that one of these ways will be better than any of the others.

The development in the General Electric Research Laboratory of processes for producing tungsten filaments is a typical example of convergent research. Today we can look back and recall how, at first, innumerable unsuccessful efforts were made to produce tungsten in the filament forms; then after it was first produced, we marvel at the vast number of processes which then sprung up—the various squirting and pressing processes, some of them hopelessly involved and doubled back on themselves; and finally we remember that the entirely new process, the drawing process, proved to be the most direct and best of all the solutions to the problem.

There is also another difference between convergent and divergent research, and that lies in the difference in the chance of obtaining results. In the latter type of research, the investigation moves in the direction of least resistance, while in the former, the industrial research, the investigation has to be forced toward some goal concerning which there is a mathematical probability that it will never reach. Each man, therefore, engaged in convergent research, has a definite probability factor regarding the solution of any one problem he is investigating. This factor is equal to the product of a time factor by a fraction determined by his personal characteristics, intelligence, perseverance, inventiveness, etc., as related to the particular problem under investigation. Of course, if the problem is incapable of solution by any human being, then the investigator's characteristics, intelligence, inventiveness, etc., as related to the problem, are equal to nothing and he has a zero probability factor.

Going to an extreme, we find a few men in the world, such as one in the General Electric Research Laboratory who has done most of the metallurgical work on the element tungsten—such men as seem to me to be blest with a unity probability factor regarding every problem capable of solution. It is to be supposed, of course, that the company would prefer to have all its men with unity probability factors, but such men are extremely scarce, so that it has to be satisfied with men whose fractional probability factors are as high as it is possible to secure. It might almost be said that the company's chances of getting returns from the men in the Research Laboratory are equal to the sum of the probability factors of these men, e. g., if the company employs twenty men and the average probability of each man regarding the solution of the problem or problems assigned him, is equal to one fourth for a period of one year, then the company should have five problems solved by the end of the year. This theory, of course, becomes more nearly mathematically true the more men the company employs. Of course, as far as the element of chance is concerned as related to the individual research man, the General Electric Company sees to it that it does not affect his livelihood.

In concluding this article, it should be said that in addition to the excellent conditions for investigations in the Research Laboratory as already outlined, there are other conditions which in themselves render the research work almost ideal. In the first place, the investigator is surrounded by a group of men which, for enthusiasm and scientific training, could hardly be excelled by a similar group anywhere in the world. In the next place, the resources which the General Electric Company can give him in the electrical field are enormous, and the capital (over $200,000) spent annually on the laboratory, is great, compared with the resources and capital connected with the research in most other laboratories. In fact, as regards the relations between the company and the investigator, the situation is simply this, that provided the probable results are commensurate with the expenditure of carrying out a particular investigation, time and money are of no consideration.

The Structure of the Atom—IV*

The Physical and Chemical Properties of the Atom Explained in the Light of Modern Theory and Experiment

By Sir J. J. Thomson, F.R.S.

Continued from SCIENTIFIC AMERICAN SUPPLEMENT No. 1946, page 251, April 19, 1913

WE will now resume the consideration of the construction of the atom, on which I have touched in my last lecture. I have shown that negative corpuscles can be obtained from the atom, and that it is possible to form some kind of estimate of the total number of these present. The limits found, it is true, are not very close, but nevertheless, several lines of investigation lead to the conclusion that this number is of the same order as the atomic weight. The researches in question indicate, in fact, that this number lies between two and three times the atomic weight, and it is almost certainly less than five times the atomic weight. The problem that then arises is how to find, within the atom, accommodation for this large number of corpuscles, which mutually repel each other. They must in some way be bound together by positive electricity, and I have assumed accordingly that the negative particles are distributed through a region of positive electricity, which counterbalances their mutual repulsion. It is impossible to form any really adequate theory of the forces which do keep the system of negative particles together. I have, however, worked out the distribution of the particles on the basis that they are distributed through a sphere of positive electricity, and are governed by the same laws that would apply if the field of force were uniformly distributed. It should, however, be pointed out that I have no definite proof that a negative particle, even outside the atom, exerts the same attraction in all directions, and that this attraction varies as the inverse square of the distance. It is, in fact, quite possible that the force the corpuscle exerts is not the same in every direction. If this is true for free corpuscles, still greater difficulties arise when the particles are confined within the interior of the atom. The laws of electric attraction, which have been proved by experiment, express merely the average effects of countless millions of particles and it is a great assumption to say, even if we regard the atom as a sphere, that the laws of attraction and repulsion are the same inside this as within a sphere of finite size. My only justification for making this assumption is its convenience, since if the laws are the same in character within the atom as inside a large sphere, the problem as to the distribution of the particles becomes comparatively easy, and it is possible to deduce the manner in which the negative corpuscles will then arrange themselves.

It turns out that they do so in rings or shells, the arrangement resembling that of the floating magnets which I described in my last lecture. The number in each ring depends upon the law of the force, but whatever this law of force, we get a discontinuous distribution of the particles in rings or shells, but the number in each ring will vary with the law of force assumed. I do not propose to discuss here the mathematical problem of finding out the way in which the particles would group themselves, but I shall assume that they do so in a successive series of rings. I shall for the present, moreover, confine my attention to the particles at the surface of the atom. It is to these particles near the surface that the whole of the chemical properties of the atom are probably to be attributed, and they are also responsible for the absorption of light and for the attractions developed between neighboring atoms.

I shall therefore regard the atom as consisting of particles near the surface, surrounding a dense central mass made up of other negative particles and of positive electricity, which form what I shall call the core of the atom. It is only since the discovery of Röntgen rays, and of the penetrating radiations emitted by the radioactive elements, that it has been possible to reach this core. Apart from these agents, it is very difficult to recognize, for example, hydrogen, as it passes from one compound to another. There is not much similarity between the hydrogen in gaseous hydrogen and the hydrogen in the molecule of prussic acid. This arises because in chemical combinations the distribution of the corpuscles near the surface of the atom is changed. The core, nevertheless, remains unaltered, as can be proved by adopting such searching means for attaining this core as Röntgen rays or the radiation from radioactive bodies. When these agents are employed, each atom exhibits the same distinctive properties in all its combinations. The characteristic secondary Röntgen radiation and the obstruction offered to the β rays are, in fact, independent of the other elements with which the atom in question may be combined.

The properties which depend upon this inner core of negative particles and positive electricity are unaltered by chemical reactions, which affect merely the particles near the surface. When we get down to this core we find that the variation of properties with the atomic weight is much more simple than that of the properties associated with the outer surface. In the latter case there is a certain periodicity which is expressed by Mendelief's law. If the "inner core" properties of an atom are plotted against the atomic weight we get a curve such as indicated in Fig. 1, which shows no periodicity. The "hardness" of the characteristic Röntgen radiation, for example, changed quite continuously as the atomic weight increased. If, however, such a character as valency, or properties associated with the visible spectrum of an element, are plotted against the atomic weight, we get a curve showing successive peaks, as indicated in Fig. 2. This constitutes a very marked distinction between the "surface" and the "core" characteristics, the latter depending on the atomic weight in a much more simple manner than the former.

It is the surface properties which cause different atoms to stick together. Let us consider, for example, an atom with just one negative particle in its outer ring, such as is represented in Fig. 3. Such a particle will be pulled in by the positive electricity at the core, and pushed out by the negative particles there, and will thus take up its position at such a distance from the center that these two forces are in equilibrium. It will, however, be quite free to move, so long as its distance from the center is the same. It has thus great freedom of movement, and so light a mass that it will travel round very easily.

In what followed I shall neglect entirely the inner core. Let us suppose then that a second similar atom is brought near the first. The two negative particles will repel each other, and ultimately a condition of things will be established such as represented in Fig. 4. Here the particle of the first atom is attracted by the positive electricity of the second, and repelled by the negative particle. The former being the nearer, however, there is on the whole an attraction and the two atoms will cling together. It is important to note that if the negative particle is movable in this way, the atom will be attracted by either a positive or a negative charge, while if the corpuscle were rigidly fixed, there would be an attraction to a positive charge, but a repulsion from a negative one. It follows, therefore, that the fixing of the corpuscle would diminish the likelihood of an attraction. This consideration is of very considerable importance in discussing the combination of various kinds of atoms.

[To illustrate this, Sir J. J. Thomson showed that when a number of magnetic needles were mounted on pivots fixed

* The fourth of a course of lectures delivered by Sir J. J. Thomson at the Royal Institution, London, and reported in *Engineering*.

on a suspended platform, the attraction exerted on the latter by a neighboring magnet was greater than when the needles were removed from their pivots and laid down at random.]

When two atoms are arranged, as in Fig. 4, mutually attracting each other, it will be seen that the corpuscle in each is no longer free, but fixed in position by the electrical forces acting on it. It can no longer move around freely, but must swing with it the whole heavy mass of the molecule. I am inclined to regard chemical forces as analogous rather to the forces between magnets than to the forces between opposite charges of electricity. It is, I admit, generally considered that in a molecule of hydrochloric acid there is an electro-positive atom of hydrogen united with an electro-negative atom of chlorine. To this theory there are, I think, some serious objections. From this point of view one atom in the combination has an excess of negative electricity, and the other atom an excess of positive electricity. I wish, therefore, to mention some facts in disaccord with this. If it were true that in chemical compounds some of the atoms carry a positive and the others a negative charge, then we should expect that, on splitting up a compound by raising its temperature, the one component would be positively electrified and the other negatively electrified. Hence a dissociated gas should consist of a mixture of positive and negative ions, and it would thus be a conductor of electricity. Many experiments on this head have been made at the Cavendish laboratory with Mr. Mond's nickel carbonyl, a gas which dissociates at temperatures below that of boiling water. It is, therefore, very easy to experiment with, and these experiments showed that on dissociation it does not become a conductor. All gases, whether dissociated or not, do show some traces of conductivity, but the conductivity of dissociated nickel carbonyl is no greater than that of any other gas. It would seem, therefore, that the atoms of nickel carbonyl can not be electrified.

If, moreover, the atoms were electrified by chemical combination, there must, since they were neutral to start with, be a passage of electricity from one atom to the other during the progress of the readjustment. We should therefore expect for the moment that the electricity would be loose and the gas become a conductor. In fact, for a long time there was little doubt but that this was actually the case, some experiments seeming to show this very clearly. Thus if a Bunsen burner is held near a charged electroscope, it discharges it, and it must be admitted, therefore, that such a flame has considerable conductivity, which has been interpreted as being due to the chemical combination proceeding. The Bunsen flame is, however, a very hot one, and if the experiment is repeated with a cool flame, such as that of burning ether, there is no loss of charge from the electroscope, although chemical combination is proceeding with vigor. The conductivity of the Bunsen flame is, in fact, due to another cause, viz., that all solid particles, if sufficiently heated, emit electricity. The temperature of the Bunsen flame is sufficiently high to produce this liberation of electricity, while that of the ether flame is not. This behavior of heated solid bodies is illustrated by the facts that the electroscope can also be discharged by bringing near it a red-hot iron ball.

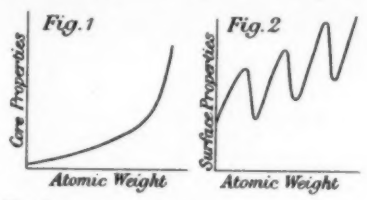
[To show further that conductivity was not necessarily associated with chemical combination the lecturer exposed to diffused light a mixture of chlorine and hydrogen. Immersed in the mixture was a plate coupled up to the electroscope, and it was shown that the latter retained its charge while the reaction proceeded. The progress of the reaction was rendered visible to the audience by throwing on the screen the shadow of a water-gage which was coupled up with the reaction vessel. The hydrochloric acid, as formed, was absorbed by the water, so that the level of the gage fell.

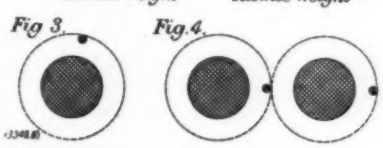
Referring to the experiment just described, Sir J. J. Thomson proceeded:]

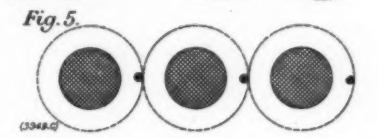
This experiment constitutes an argument in favor of the view that in chemical combinations there is no bodily transfer of a charge from one atom to another, and supports the theory that the attraction between the two is more analogous to that between two magnets. The point must not, however, be regarded as definitely settled. Some experiments by Haber seem, indeed, to indicate that the alkali metals can emit negative charges, although at temperatures insufficient to account for the phenomenon. Haber exposed fresh surfaces of the alkali metals to phosgene, and found that the conductivity of the latter was considerably increased, though there was no increase in temperature. Again, if oxygen is slowly drawn over phosphorus, the phosphorous vapor which comes over has a slight conductivity. Nevertheless, in the vast majority of cases, it is found that chemical combination does not necessarily imply conductivity.

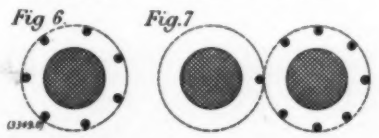
Another argument against the view that the atoms in compounds are charged can be based upon the behavior of positive rays. Suppose, for example, that in carbon monoxide the carbon is always positively electrified and the oxygen negatively electrified, then when CO is split up in the discharge-tube, the carbon will be attracted by the cathode and the oxygen repelled, and we should thus get more carbon atoms coming through the cathode than atoms of oxygen. Actually, however, it is found that the number of each is about the same, a fact which indicates that it is not probable that the constituents of carbon monoxide are oppositely electrified, and that the attraction between the two elements is more analogous to that of two magnets than to that of two opposite charges of electricity.

Two atoms arranged as in Fig. 4 resemble a magnet. By bringing up another in a particular direction, as in Fig. 5, there might be, it will be seen, a considerable attraction developed, but in all other positions the attraction would be small, since the corpuscles in the original pair had no freedom of movement. This, then, is the difference between a "saturated" and a free atom. In the free atom the corpuscle can adapt itself, and attraction can thus be exerted over the whole surface of the atom. In the molecule, however, the field of attraction is much more limited, while that of the atom extends over its whole surface. Nevertheless, if attacked in the right place, the molecule can exert very considerable forces. If we compare the average forces exerted between molecules with the forces between atoms, the former are found to be much smaller, but are not, in comparison, insignificant. The intensity of such forces can be represented by considering the work necessary to separate two atoms and the average amount necessary to separate two molecules. If one starts in the right position, the latter may, as stated, be very large, but if taken all round, it is much smaller. The work required to separate the atoms in a molecule varies with the compound, but is of the order









of 3 to 4 volts. In this conventional, but very convenient, method of representing such work, the work is represented by the number of volts through which a negative particle must fall to acquire the same energy. On this basis the work required to separate the molecules of a number of different gases is represented by the voltages tabulated below:

Kind of Gas.	Voltages.
He	$\frac{1}{117}$
Ne	$\frac{1}{110}$
Ar	$\frac{1}{38}$
Kr	$\frac{1}{44}$
X	$\frac{1}{83}$
H_2	$\frac{1}{95}$
N_2	$\frac{1}{72}$
O_2	$\frac{1}{60}$
CO_2	$\frac{1}{32}$
Ethylene	$\frac{1}{34}$

It will be seen that while, to separate two atoms of a compound, work equivalent to a fall of 3 or 4 volts is needed, the corresponding work needed to separate two particles of neon is only $\frac{1}{110}$ volt, and this is the lowest figure yet found.

The above table gives a kind of idea of the magnitude of the attractive forces between molecules. The method by which they have been estimated was due to the late Mr. Sutherland, who is responsible for some very important work on the atomic theory of matter. Mr. Sutherland has shown that in considering the collisions between molecules it is necessary to take into account the attractive forces acting. If the molecules simply resembled billiard balls, they would not strike each other so often as they would were there a strong attraction between them. In the latter case the mean free path would be reduced. Sutherland has calculated out the effect of such an attraction on the mean free path, and has shown that it depends only on the average work required to separate two molecules. For each gas the actual mean free path can be determined by measuring its viscosity, hence it is possible to deduce the average work needed to separate two molecules.

An atom with only one free corpuscle is to be regarded as a monovalent electro-positive element. The number of loose particles correspond to the valency of the element. In this connection I wish to call attention to the fact that it is not possible to have more than a certain number of such particles in a ring. Chemistry affords some evidence that the maximum number which can occur in the outer ring of an atom is eight. Suppose, then, we brought together an atom with one loose particle and an atom with seven loose particles, such as indicated in Fig. 6. The one loose particle, moving round as indicated in Fig. 7, would be equivalent to the addition of an eighth loose particle to the second atom, and this is the maximum number it can have. If then a second monovalent electro-positive atom were brought up, this would be equivalent to trying to form a ring with nine particles, which is impossible, and the atom with seven loose corpuscles could not therefore hold two atoms, each with one loose corpuscle. The atom with seven loose corpuscles is accordingly to be regarded as a monovalent electro-negative element. If there were six instead of seven loose corpuscles, it could hold two atoms each with one loose corpuscle, as this would again be equivalent to forming a ring with eight. Similarly with five loose corpuscles, three of the first kind of atoms could be held, while with four loose corpuscles, four electro-positive monovalent atoms could be held. The valency is, therefore, represented by the amount by which the number of loose corpuscles differs from eight.

We could, however, form, in certain cases, another kind of compound. Starting with the original model, with only one corpuscle, it will be seen that seven more could be added before saturation. Hence, if such an atom acted as an electro-negative, in place of as an electro-positive element, it would have a valency of seven, and similarly an atom containing three loose corpuscles would act as an electro-negative element having a valency of five. Each atom had, therefore, two valencies, according as it acted as an electro-positive or an electro-negative element, and the sum of these valencies was always eight. I understand that Abegg has shown that there are chemical grounds for believing that this is actually the case, and, in fact, it was for this reason that I have assumed that eight is the critical number of negative corpuscles in an atomic ring.

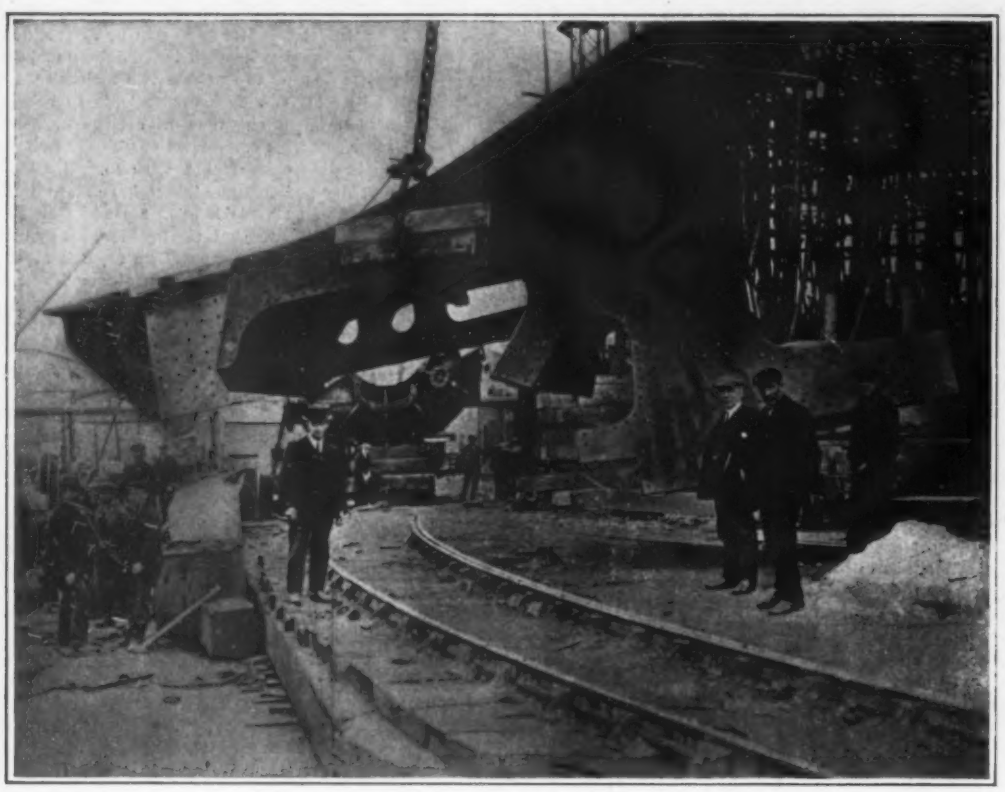
To be continued.

Traveling Through Inter-stellar Space

What Type of Motor Would You Employ?

How could the trip to the moon be realized? There is the method of Jules Verne, in which the traveler is shot off the earth by a cannon. But another expedient is suggested in the French journal *Cosmos*. Any apparatus depending on the atmosphere for its propulsion and sustentation, such as the balloon and the aeroplane, would of course fail in inter-stellar space. The device selected by the writer in *Cosmos* is the skyrocket. Seasonable interest is attached to this suggestion by the recent attempt of Law, whose ambitions indeed did not extend to the moon, though his course proved to be directed straight enough toward another astral body—Mother Earth herself. But we are not here concerned with practice. What we have in mind is theory. It is true that the skyrocket under ordinary conditions depends for its propulsion at least in part upon the reaction of the air. But this is not absolutely essential to its progress. Its own recoil, as it discharges its trail of gas and solids, would be capable of propelling the rocket even in empty space. In fact, the rocket would gain a certain advantage in traveling through space instead of through the air, owing to the absence of head resistance. M. R. Esnault-Pelterie has worked out the capabilities of a conveyance built on this plan. The results are far from encouraging—the efficiency of the motor would be very low. Theoretically, in order to carry a mass of one pound from the earth to an indefinite distance, we should have to do an amount of work equal to 21 million foot-pounds. The "reaction motor" of the rocket would in point of fact expend 713 million foot-pounds. The efficiency would therefore be only 0.029 or about 3 per cent. This is discouraging when we consider that steam, gasoline and other motors attain efficiencies of as much as 50 per cent.

When we come to consider the source of motive power to be carried on board we find ourselves in still greater difficulty. Putting the weight of the passenger at 165 pounds, he would have to carry on board 660 pounds of dynamite for the trip to the moon—237,500 miles—and back. Radium would be a more condensed source of energy: 55 pounds would suffice. But unfortunately it gives off its energy so slowly that even after 1,760 years its store would only be reduced to one half.



A Part of the Great Stern Casting. Weight 62 Tons.

The Artist's Anticip

The "A itan

The Latest Addition to Anglo

BUT two weeks ago we reported the launching of the world's greatest steamship, the "Vaterland," of the fleet of the Hamburg-Amerika Line. As the current issue of the SCIENTIFIC AMERICAN SUPPLEMENT is passing through the editor's hands, the Cunard Line is making the last preparations for putting afloat its latest leviathan, the "Aquitania." In point of size she falls a little short of the "Vaterland," her measurements being: Length, 901 feet; breadth, 97 feet; depth from keel to boat deck, 92 feet 6 inches; gross tonnage, 47,000 tons. Her speed is estimated at 23 knots. There will be accommodation for 3,250 passengers and a crew of nearly 1,000.

The "Aquitania" has been constructed upon the Clyde, and her great size and weight, exceeding that of any boat previously built in the same yards, involved the consideration of unusual conditions, and demanded arrangements being made on a scale of magnitude never before required on the Clyde.

In order to lay down the leviathan the whole face of the yard had to be changed. The ground on which the ship was to be built had to be specially prepared and strengthened, piled and cross-piled. Over the cross piles were placed layers of steel plates, then quantities of cement, it being essential that the ground should not yield an inch at any point.

New crane systems had to be installed for lifting the heavier materials on to the wider, longer slip.

The same berth was used as that upon which the "Lusitania" was built, but owing to the much greater length of the "Aquitania" the preparation of the ground had to be very considerably extended.

The berth being in line with the river Cart, which flows into the Clyde almost opposite the yard enabled the builders in launching the ship to avail themselves of this natural advantage.

The new ground was prepared as that for the "Lusitania." The part on which the earlier ship structure had rested required, of course, comparatively little treatment beneath its surface. The blocks were then put down, the keel laid, and the frames erected.

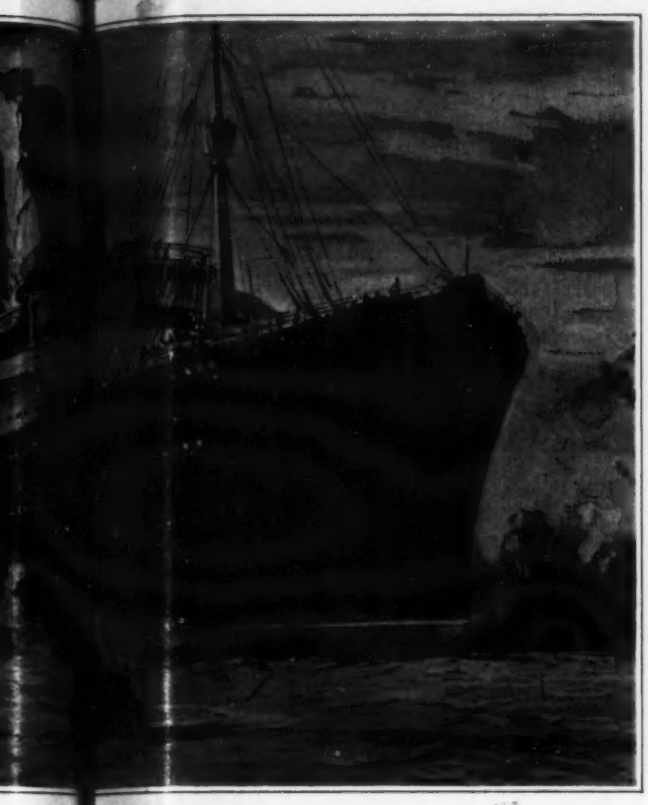
In addition to the preparations in the yard the river had to be deepened and widened, and the builders' fitting-out basin at Clydebank has also had to be dredged in order to accommodate the liner during completion.

A SHIP WITHIN A SHIP.

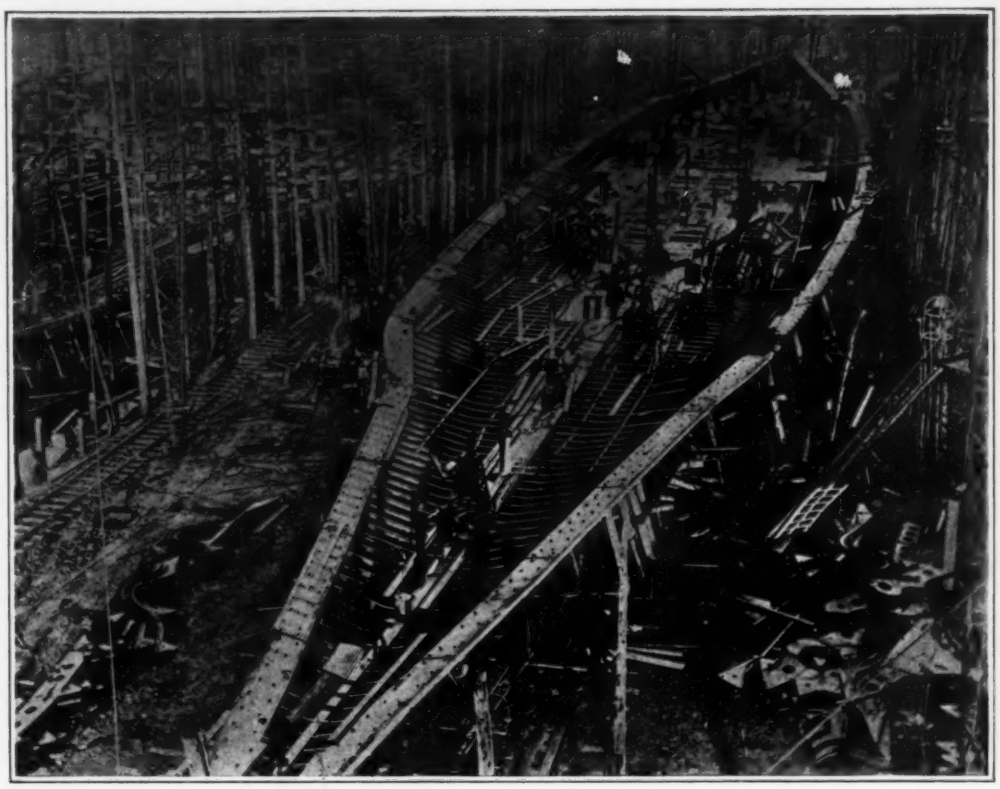
An important feature in the "Aquitania," as in the "Lusitania" and "Mauretania," is that extending

Clay Pit in Which the Experimental Wax Model of the Great Ship was Cast.

Aft Framing, Stern



's Anticipa the Completed Vessel.



The Inner Bottom of the Double Shell, Looking Forward.

e "Aquitania"

ition to Anglo-American Fleet

structure ively little were than ted. d the river uilders' fi- be dredged mpletion.

as in the extending

throughout the most vulnerable parts, there is that great desideratum, a ship within a ship. In other words, there are two shells, the inner as well as the outer shell, both being watertight. The space between the outer and inner skins averages about 15 feet, and at short intervals there are bulkheads dividing this intervening space into relatively small compartments. It will be understood, therefore, that any fracture of the outer shell due to collision will result in the ingress of the sea being limited to a small area at the side of the ship. In addition to this important provision, there are sixteen bulkheads extending athwartship from the port to the starboard side. Further provision is made by the development of the system of fitting watertight decks, introduced in the "Lusitania" and "Mauretania."

It will thus be seen that from a point of view of strength the "Aquitania" embodies the main features of the "Lusitania" and "Mauretania," with additions consequent upon increased beam and length. The "Aquitania" will also be fitted with Frahm's anti-rolling tanks, which have proved so successful in the "Laconia," which plies between Boston and Liverpool in summer, and between Boston and the Mediterranean.

The passenger accommodation will be provided on a scale commensurate with the great size of the ship. The first-class public rooms will include:

On "A" Deck—Drawing room, hall and galleries, lounge, smoking room, and veranda cafés.

On "D" Deck—Foyer, restaurant, grill room, and dining saloon.

There will also be a gymnasium and swimming bath.

The second class public rooms include a drawing room, lounge, smoking room, dining saloon.

The public rooms and promenade decks (both open and covered) allotted to third class will all be of the most generous dimensions.

There are altogether eight decks on which passengers are carried.

MOTOR LIFE-BOATS.

The division of the ship into watertight compartments is much more extensive than is required by any regulations, and exceptional conditions might therefore have been obtainable in connection with the life-boats, but the company fifteen months ago submitted their plans to the Board of Trade for an installation of life-boats to accommodate every passenger on board. Two motor life-boats will also be provided.

ming, Stem and Brackets.

Dressing the Wax Model, Used in the Experiments Made to Determine the Lines of the Ship.

Commercial and Financial Aspects of Gas Manufacture—I*

A Retrospect of the Development of a Great Industry

By George B. Cortelyou

HISTORICAL

About one hundred years ago, two of the leading nations of Europe brought forth, independently of each other, an invention which was destined to become a factor mightier than almost any other for the promotion of human comfort, for advancing civilization, and for giving employment to great industrial armies.

On this occasion, therefore, we celebrate the birth of a great industry; and it is fitting that we recall the names of those patient pioneers whose struggles are matters of history, and whose subtle creation illumines the civilized world. Among the names which we honor to-day are those of Van Helmont, Clayton, Murdock, Lebon, Clegg and Winsor, but it is generally conceded that to William Murdock belongs the credit of being the first to develop the gas industry along practical lighting lines.

From Murdock's own account we learn that, in 1798, he removed from Cornwall, where he had conducted important experiments, lighting his own house (1792), to Boulton, Watt & Company's works for the manufacture of steam engines at the Soho Foundry, near Birmingham, where he constructed an apparatus on a large scale which was applied to the lighting of the principal building. His experiments were continued with some interruption until the year 1802, when a public display of the light was made in the illumination of the manufactory at Soho, on the occasion of the celebration of the "Peace of Amiens." A contemporary writer states: "This remarkable illumination was the first public display (of gas lighting) in this country and at the time produced a very strong impression upon the inhabitants of the town. The illumination of Soho works on this occasion was one of extraordinary splendor. The whole front of that extensive range of buildings was ornamented with a great variety of devices, that admirably displayed many of the varied forms of which gas light was susceptible."

Murdock's efforts were stimulated by news of the activities of M. Lebon, of Paris, along similar lines. This is related in a letter addressed to Soho from which Dr. Henry published the following extract: "I don't know exactly at what time the first trials were made or published in France. The first notice we received of them here was in a letter from a friend at Paris, dated November 8th, 1801, in which he desired me to inform Mr. Murdock that a person had lighted up his house and gardens with the gas obtained from wood and coal and had in contemplation to light up the city of Paris."

The testimony of James Watt, Jr. (son of the great inventor), who was associated with Matthew Boulton in the firm of Boulton & Watt, proprietors of the Soho Works, shows, to use his own words, that "At the period when the peace took place, which, I believe was in the spring of 1802, public display of these lights was made in the illumination of Mr. Boulton's manufactory, which then took place. In 1803 we erected an apparatus for the purpose of giving a light to a part of our own works and, till 1804, we continued making experiments on the gas produced, and also on the different coals out of which the gas was to be made; on the manner of making the retorts best adapted to the purpose; upon the materials and construction of the pipes; upon the size and construction of the gasometers; upon the economy of the different sorts of burners, etc. The experiments were very long and attended with a great deal of expense. We were out of pocket £4,000 or £5,000, and are so at this moment for the experiments and machinery."

In Hunt's "History of the Introduction of Gas Lighting," we are told that: "It was the fear of being anticipated by Lebon that quickened the firms' pace and finally overcame their reluctance to embark in this new venture. Without Lebon, therefore, Murdock's invention might have remained indefinitely in the background; but, it may with equal justice be said that without Murdock, Lebon's ideal could not have been realized. There is no evidence that either Murdock or Lebon aimed at anything beyond a number of separate and independent installations; but Lebon's idea of 'lighting a part of Paris with it' seems to have fired the imagination of his follower, Winsor, in whose hands a public supply of gas lighting became a reality, although this was only made practicable by the achievements of Murdock and the development of engineering and industrial art."

Lebon was granted a patent, for a term of 15 years from Spetember 28th, 1799, as shown by the records in the Patent Office at Paris.

Frederick A. Winsor, contemporary of Murdock and Lebon, is described as a man of little experience, but possessed of an extremely sanguine temperament and an unbounded imagination, combined with determination and ingenuity. He was the first to advocate publicly the distribution of gas from a central source, and was the promoter of the first chartered gas light company. The London press spoke of him most disparagingly and described his scheme of gas lighting as "wild, absurd and extravagent in its conception and fraught, with the greatest danger in its execution," and alluded to Winsor's proposal for "enlightening the inhabitants of London" as "fire of wind." Winsor was himself responsible for much of this opposition by reason of his extravagant statements as to profits (as much as 1,000 per cent being promised) of the venture. Indeed, a perusal of his flowery prospectus would give pause even to the modern advertising man, and the circus poster in its plamiest days hardly approached its flights. For instance, in one of his pamphlets, after claiming such utilities as "tanning skins," "smoking bacon and hams," and "fixing color in dyeing," he says, "As to illuminations they may be carried on to the utmost extent of beauty and variegated fancy, by this docile flame, which will play in all forms, submit to instant changes, ascend in columns to the clouds, descend in showers from the trees, walls, etc., arise from the water, and even in the same pipe with a playing fountain. The constant varying of the flame in rooms and gardens between flaming pyramids, festoons, garlands, roses, flambeaux, etc., afford the spectator a most delightful sight, cherish the soul and create good humor by uniting convenience, utility and pleasure."

In 1803 and 1804 Winsor publicly exhibited his system of illumination by coal gas at the Lyceum Theatre, London. He showed the manner of conveying the gas to different parts of the house, and, by the use of various kinds of burners, he was enabled to display something of that variety of form which may be given to the flame. His exhibitions proved that the intensity of coal gas rendered it less liable to be extinguished by strong and sudden gusts of wind, and he also showed that if properly managed the burning of it would not produce smoke or throw out sparks such as often fly from the burning wicks of lamps or candles, a circumstance which rendered gas a desirable kind of light, as being less dangerous in its use than either of the other forms. Afterward, Winsor moved his exhibitions to Pall Mall where, early in 1807, he lighted up a part of one side of a street, which was the first instance of this kind of light being applied to such a purpose, and to him, therefore, belongs the credit of initiating the system of public gas lighting.

As the projector of the National Light and Heat Company, Winsor is stated to have raised nearly £50,000 by subscription for this purpose, all of which, however, was squandered upon commercially unproductive experiments.

In 1809 Winsor projected a new Light and Heat Company, and applied to Parliament for an act to incorporate it. This is an important fact in the history of the gas industry, for it was the foundation of the London and Westminster Chartered Gas Light and Coke Company. The capital proposed to be raised at this time was £200,000. The persons who applied for the act had many difficulties to combat, arising both from interest and prejudice. Their projects were represented as visionary and the execution of them fraught with considerable danger. On this occasion they were opposed by Mr. Murdock on the ground of his priority of right to the discovery. The application terminated unsuccessfully, partly because of the unfavorable impressions produced by Winsor's extravagant claims. Murdock's opposition to Winsor resulted in Parliament protecting the appliance manufacturers against possible competition by the lighting company.

In 1810 another application was made to Parliament by the same parties, and though it met with some opposition an act was passed authorizing His Majesty to grant them a charter within three years from the time of passing the act. Thus Winsor's plan of a National Light and Coke Company was in part accomplished by the formation of a local gas light and coke company. The incorporation of this company, which occurred in April, 1812, the centenary of which we celebrate, was an important step in the direction of placing the new industry upon a basis that promised its permanent establishment and increased the probability of its ultimate success. Experience had already proved that the resources of the individual were inadequate to cope successfully with undertakings of such magnitude and cost. From calculations, as well as from actual surveys that were made, it appeared that the expense of laying down pipes for the city of Westminster alone would be £150,000, without including any other expense.

In 1813 Westminster Bridge was lighted with gas. About this time the City of London Gas Light Company was established, and two others were projected for the metropolis, one in Southwark, the other in the eastern district. From the time of the formation of the Chartered Gas Light and Coke Company, to the year 1813, experiments had been carried on by Messrs. Winsor, Accum and Hargraves, at which time the Company was almost on the point of dissolution.

Samuel Clegg was engaged as engineer of the company, he having been educated as an engineer in Boulton & Watt's foundry, at which time his attention was first directed to the practicability of distilling gas from coal, when assisting in the illumination of the Soho manufactory.

In 1815 Clegg invented and patented the gas meter and governor. The first meter consisted of two large bladders, filled alternately with gas, and contained in two cases weighted to a certain pressure, the valves being sealed with quicksilver. Though credit for the original invention and construction of the gas meter belongs to Clegg, it has been very materially improved by Samuel Crosley and John Malam. It is to the introduction of this simple instrument, now in universal use, that a great deal of the success of gas lighting must be attributed.

Thus Mr. Clegg seems to have been the pioneer in many of the important inventions connected with gas lighting. Besides the gas meter he introduced the cylindrical gasholder and an automatic pressure regulating device. It is he also who was chiefly responsible for the success of the original Chartered Gas Light and Coke Company, and he was the first man to commercialize city gas lighting on a large scale.

In 1816 gas had become very common in the city of London.

Paris was first lighted by gas in 1820.

In 1833 the French National Gas Company was projected for lighting Boulogne-Sur-Mer. The capital of £10,000 being too small, the company was taken over by the European Gas Company and capitalized for £200,000 for the purpose of lighting other European towns.

Gas was used at Havre, Caen and Amiens, in 1835; at Nantes and Rouen in 1846. The plants for all of these gas works were sent from England.

Before the second London company was chartered our own city of Baltimore granted a charter to the first company to be regularly organized for the purpose of exploiting gas for the illumination of streets and cities in America. Gas chronology tells us that Baltimore was not only the first city in this country to be lighted with gas, but that it was also the first city in which gas meters were manufactured in the United States, and gives the name of Samuel Hill as the meter maker.

A brief historical summary of gas development in the United States is given in the U. S. Census Reports for 1910, from which the following is adduced:

The history of the gas industry in this country dates from 1806, at which time David Melville, of Newport, R. I., lighted his premises by means of coal gas which he had manufactured thereon. This took place nine years after the experiments in England. The apparatus as used by Melville was necessarily crude, but underwent improvements from time to time until, in 1813, he secured a patent and later used gas for the lighting of a cotton mill in Watertown, Mass. Gas was also used at about this time in a mill near Providence, R. I., and was employed in 1817 as an illuminant in a lighthouse. The growth of the industry was at first slow; but, with the advances in the details of the construction and operation of gas plants, the improvement and development of special tools and appliances, and the increasing knowledge gained by experience of the laws of physics involved, there came a much more rapid growth. As early as 1816 a company was chartered in Baltimore, Md., followed (1821) by the formation of a company in Boston, Mass. New York city adopted gas lighting in 1823, and several years later companies were formed in Brooklyn, N. Y., and Bristol, R. I. New Orleans adopted gas about 1835, twenty-nine years after Melville introduced the new illuminant in this country.

A proposition to light Philadelphia with gas was made in 1803, and a similar one was made in 1817, but both offers were rejected. Repeated efforts were made thereafter looking to the lighting of the city with gas,

* Address delivered on the occasion of the celebration of the Centenary of the Use of Gas as an Illuminant, Franklin Institute, Philadelphia, Pa., April 19th, 1912.

but it was not until March 21st, 1835, that an ordinance was passed providing for the construction of the works. The plant was completed February 8th, 1836.

OBJECTIONS RAISED TO THE INTRODUCTION OF GAS.

Like most inventions, gas lighting was not at first taken seriously. It seemed to the American and European world of 1800 to be on a par with the Laputan philosopher's scheme for making sunshine out of cucumbers. People were afraid of this "burning air," as it was called, and could not be convinced that fire or explosion would not be the inevitable result of its general use. When that daring New Yorker, Samuel Leggett, first lighted his house, No. 7 Cherry Street, with gas, people stood at a respectful distance and looked at it much as they might have looked at the witches dancing in "Kirk Alloway."

In Europe the prejudice against gas lighting at the time of its introduction was equally strong. Napoleon ridiculed it, and said. "C'est une grande folie." In 1803, Sir Walter Scott wrote to a friend: "There is a madman proposing to light London with—what do you think? Why, with smoke!" Yet Scott himself had Abbotsford piped for gas not many years later. Clegg gives an account of the horrors of the lamplighters when they first beheld the burning gas and how he was obliged to light the lamps for some time on account of the fears of the people. Even such men as Sir Humphry Davy and Sir Joseph Banks were unable for many years after this to overcome the prejudice which existed in their own minds concerning it and they thought the scheme a wild and dangerous one.

Another concrete instance of this prejudice can be cited right here in Philadelphia. On November 28th, 1833, a petition, signed by several hundred of the excellen people of that city, was addressed to "The Honorable the Select and Common Councils of the city of Philadelphia," protesting against the use of gas, in the following terms:

"Gentlemen: The subscribers beg leave respectfully to remonstrate against the plan now in agitation for Lighting the city with Gas, as they consider it a most inexpedient, offensive, and dangerous mode of lighting. In saying this they are fully sustained by the accounts of Explosions, Loss of Life, and great destruction of property, where this mode of lighting has been adopted.

"We consider Gas to be an article as Ignitable as Gunpowder, and nearly as fatal in its effects; as regards the immense destruction of property, we believe the vast number of fires in New York, and other cities, may be in a great measure ascribed to this mode of lighting the leakage of pipes and carelessness of stopping off the Gas, furnish almost daily instances of its destructive effects. And when we consider that this Powerful and Destructive Agent must necessarily be often left to the care of youth, domestics and careless people, we only wonder that the consequences have not been more Appalling. It is also an uncertain light, sometimes suddenly disappearing and leaving streets and houses in total darkness.

"The waters of the Delaware and Schuykill, now considered the most pure and salubrious in the world, as many long voyages have fully tested, must soon, we fear, experience the deterioration which has reduced the water of the Thames to the present impure and unhealthy state, for no reservoir will be able to contain the immense fetid drains from such an establishment, and very soon the rivers must be their receptacle, to the destruction of the immense Shoals of Shad, Herring, and other fish with which they abound; the same cause must produce like effects. Salmon, smelts and other fish, formerly caught in vast quantities in the Thames, have nearly all disappeared; the constant digging up of the streets, the circumstances of the gas pipes which at the intersection of each square must come in contact with the water pipes, are difficulties and evils which we would anxiously avoid.

"In conclusion we earnestly solicit that the lighting of our city with oil may be continued.

"And your petitioners, etc., etc."

If the signers of this petition could appear upon the scene to-day and witness the splendid achievements of gas under the management of your great Philadelphia Company, I am sure they would be in favor of the "recall," at least in so far as it applied to their petition.

But the opposition to the use of gas should not surprise us. It seems a fundamental trait of human nature to oppose, for a time, everything that is new. Coal had the same prejudice to overcome. In the year 1306 the use of coal in the place of dry wood and charcoal by brewers, dyers and other artificers employing great fires, was prohibited by proclamation at London. It was held that the products of its combustion, smell and smoke were prejudicial to health and hurtful to vegetation. Its use was made a capital offense, and we are told that a man was actually executed for burning coal within the metropolis. What a boon such a law would be to the gas companies to-day!

It does not take long, however, for human nature to get used to novelty, but remarkable it certainly is, considering the difficulties of communication and the meager resources of a new country, that America was but little behind Europe in the use of the new illuminating gas.

The history of the pioneer gas companies of this country shows that in addition to, and to a considerable extent because of, the prejudice that existed against the new and supposedly dangerous illuminant, it was a very difficult matter to secure the necessary capital to erect and operate the plants, and it was some time before the industry was established on a commercially sound and profitable basis.

Gas as an illuminant has had several competitors which at the time of their appearance in the field threatened its existence. In the early days of the industry the gas manufactured had an illuminating value of about 15 to 17 candle power. Compared with the light of candles or of the crude whale oil then in use, it was considered a wonderful illuminant. This superiority was soon threatened, however, by the introduction of kerosene and improved oil lamps, the general use of which interfered seriously with the rapid increase of the sale of gas.

These conditions would have greatly retarded the growth of the industry had not the problem been solved by Tessie du Motay and Lowe, the former a Frenchman, the latter an American, who, independently of each other, were carrying on experiments which were to result in the introduction of the so-called water gas. The investigations of both du Motay and Lowe were conducted in this country, so that the development of the water gas industry is purely American. The first plant using the Lowe process was erected at Phœnixville, Pa., in 1873. At present, although the exact figures are not available, the census reports indicate that the amount of water gas sold for public use is in the neighborhood of 75 per cent of the entire quantity of gas sold.

(To be continued.)

Power from Waste Fuel

Importance of By-Products

THERE is probably no movement of greater importance at the present time in the industrial world, says a correspondent in the London *Times*, than the strenuous efforts that are being made to utilize to the utmost extent all those sources of power which have hitherto been wasted or turned to imperfect account. Within living memory millions of tons of fuel escaped into the atmosphere unburned from the blast furnaces and the coke ovens; refuse coal-screenings were allowed to be consumed in spoil-banks at the pits' mouths of our collieries; and waste heat from thousands of manufacturing operations was dispersed unused into the atmosphere. Now there are power plants for the electrical distribution of energy obtained from the gases of the blast furnace and the coke oven; installations for converting small coal into Mond-gas, which is distributed over a wide area for utilization in the internal-combustion engine; and careful systems of conservation for the surplus heat of the factory or the workshop.

With all expenses of installation and maintenance of the recovery apparatus and ample allowance for sinking fund and depreciation, it is asserted that the electrical energy derived from the blast-furnace gas does not cost more than 1/8 to 1/4 pence per kilowatt hour. It is estimated that gas-engine plants with a capacity of over 650,000 horse-power are now at work in Germany on blast-furnace gas, and the power thus generated is being largely used in the production of electricity.

UTILIZATION OF PEAT.

The employment of the Mond-gas producer is familiar in this country, and gas obtained from coal is already being utilized on a large scale in the Midland districts. The same kind of apparatus is being used by Profs. Frank and Caro for the production of power-gas from peat, with recovery of the by-products, and it is stated that by means of experiments on a manufacturing scale it has been demonstrated that the gas obtained from air-dried peat, with 50 to 55 per cent of water, possessing a calorific value of 157 B.T.U. per cubic feet, is capable of furnishing one effective horse-power for the consumption of 85 cubic feet of gas. Plant with a capacity of 3,000 horse-power is now at work near Osnabrück, using the local peat-beds for the generation of electricity. In this case the attention given to the recovery of the by-products is a factor of great importance. The raw peat contains from 1 to 1.2 per cent of nitrogen, and yields from 63 to 65 pounds of sulphate of ammonia per ton.

There can be little doubt that, if in the employment of coal for the production of power, the same care was exercised in the thorough conservation and utilization of all the valuable constitutents, a very attractive return could be obtained. It must be remembered that systems are in existence whereby this is rendered possible, and there would be no practical difficulty in securing commercial results from coal quite comparable with those now being obtained from peat by the German professors. In order to extract the utmost possible value from the fuel it is necessary to deal with it by a distillation process instead of wasting half the calorific constituents up the furnace chimney.

RESULTS OF DISTILLATION PLANT.

In a suitable plant, capable of dealing with, say, 500 tons of bituminous coal daily at the pit's mouth, the yield of each ton will be approximately as follows: (1) From 5,000 to 6,000 cubic feet of gas, with a calorific value of, say, 650 to 700 B.T.U. per cubic foot; (2) 20 gallons of oil, containing up to 7 1/2 per cent of benzine; (3) ammoniacal liquor, in the case of coal containing 1.5 per cent of nitrogen, sufficient to manufacture 20 pounds of sulphate of ammonia; (4) 13 hundredweight of residual tar-free coke, with about 2 hundredweight of small coke or fines; these last can advantageously be used in heating the retorts.

The coke might, of course, be sold as a smokeless fuel for doemestic or manufacturing purposes, but it is not in this way that the full value of the fuel would be secured. The method by which it would be used to the best advantage would consist of converting it into gas in the gas-producer, which gas, after being passed through condensers to extract the balance of the nitrogen and tar oils, would be used to generate electricity. The 13 hundredweight of coke thus utilized would yield electrical energy to the extent of upward of 1,300 hores-power, together with an additional amount of tar oil and sulphate of ammonia. Authorities give somewhat discordant estimates of the amount of nitrogen to be obtained by breaking up the coke, but this depends, of course, to some extent upon the temperature employed, in the first instance, in the carbonizing process. If the gas is obtained by the application of a low heat in the retort, in conjunction with the vacuum process, the yield in nitrogen products from the coke would be relatively high, and by a suitable condensation process further quantities of oil and tar could be recovered.

In the near future, when the question of the recovery of the nitrogen from coal will probably become a matter of even greater importance than it now is in the distillation of oil from shales, more is likely to be heard of the relative merits of high temperature and low temperature carbonization. In the past the gas manager, with no thought but the recovery of the maximum amount of gas, or the coke manufacturer, whose only object is the production of a high quality of coke, have had it all their own way, and the residuals have been a matter of secondary consideration. The time is coming when the value of the residuals, as contrasted with that of gas or coke, will receive much greater attention and the retort treatment will be studied on more general lines.

THE NITROGEN PRODUCTS.

It is a well-established fact that the nitrogen is only evolved as ammonia in small quantities when the heat applied to the retort is moderate, and that the bulk of the nitrogen must then remain in the coke, from which it can be almost wholly expelled in the gas-producer. If the object in treating the coal is to obtain the best possible yield of rich coke, the retort treatment need not be unduly prolonged and only a small volume of gas will result. On the subsequent transfer of the coke to the gas-producer for use in thick layers with injected steam in order to obtain suitable fuel for the gas engine, almost the whole of the nitrogen will be recoverable in the condensing plant. It will be a manifest advantage if the time in the retorts can be reduced to 2 1/2 to 3 hours.

It will probably be within the mark if the yield of sulphate of ammonia from the coke is taken at 45 pounds, or a total of, say, 65 pounds from the coal and coke. If the 5,000 cubic feet of gas from the retorts is used with the producer gas for the generation of electricity it would yield a further amount of current equivalent to 227 kilowatt hours, say, a total from the ton of coal of 1,527 kilowatt hours, worth, at 1 cent per kilowatt hour, $15.27.

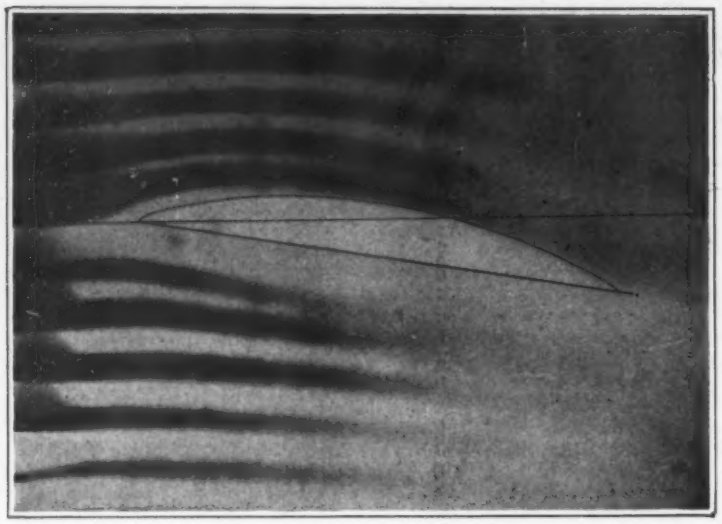


Fig. 1.—Stream Lines About Inclined Circular Segment. Record Produced by the Method First Developed.

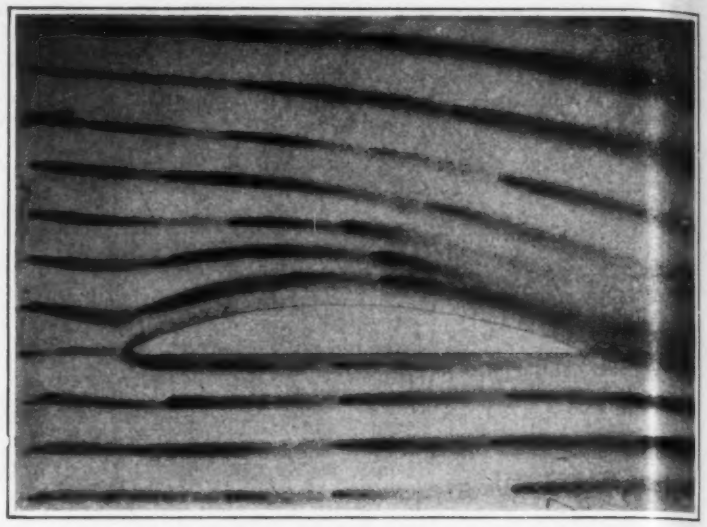


Fig. 2.—Stream Lines Around Circular Segment With Its Chord Parallel to the Direction of Blast. Velocity, 220 Feet per Second.

Stream Lines Around Obstacles to Air Currents

A New Method of Obtaining Permanent Records

By the Paris Correspondent of the SCIENTIFIC AMERICAN

THE investigation of wind pressure upon various surfaces is a subject which presents not only considerable theoretical interest, but which is also of great practical importance, especially in connection with the modern art of aeronautics. Experiments are now in progress in most civilized countries in this direction. The method followed in conducting the work may belong to one of two types. In the first class of experiment the surface under test is exposed to the wind pressure in question, and by means of special devices the pressure at different points of the surface is measured, or else the total pressure may be registered by a special instrument. One of the first to work in this direction was Prof. Langley, who used a sixty-foot track with a central mast, by means of which the test plane could be rotated around the track at a given speed. Tests have also been made in France by Abbé le Dantec, Eiffel, Capt. Cailletet and others, who used planes allowed to fall from an elevation or else rotated from a central mast as in Langley's experiment.

Canovetti experimented with large planes mounted on a car and run down a steel inclined track. As our readers know, Mr. Eiffel employs an apparatus consisting of a box containing a blower and provided with a blowhole from which the current issues and is allowed to impinge upon the test plane placed in front of the hole. Similar experiments are being conducted at the New Aerotechnic Institute, and quite recently the Duc de Guiche has used test planes carried on an automobile, and has by this method obtained very satisfactory results.

What renders the investigation of the effect of air currents upon planes placed in their course particularly difficult is the fact that air is invisible. For if we could follow the course of the individual molecules of the air as it passes the plane, we should be in a much better position to understand the mechanism of the effect observed by gross average methods.

The second of the two types of methods of which mention has been made above, as being employed in

Fig. 3.—Apparatus for Recording Stream Lines of Gas Upon Chemically Prepared Paper.

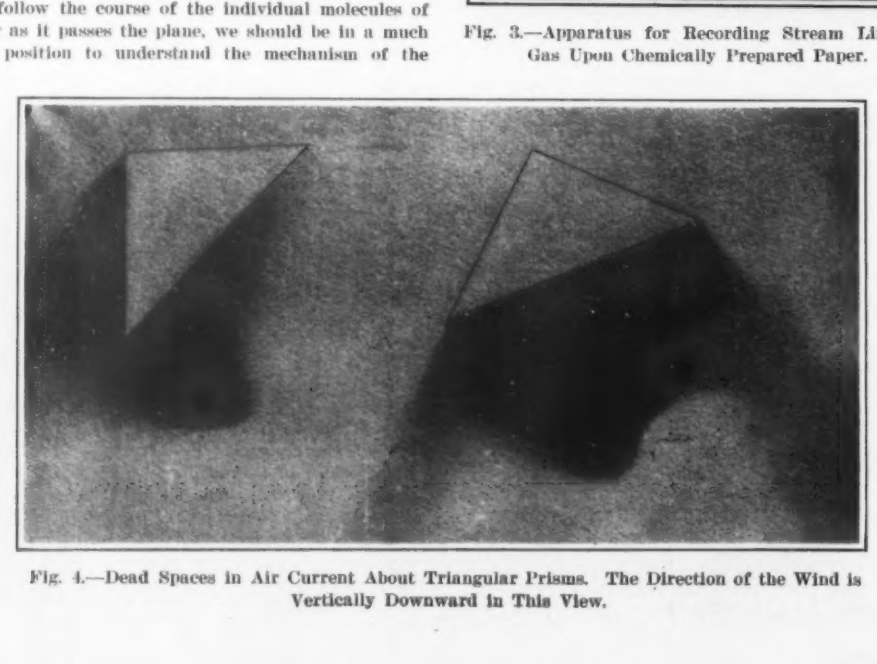


Fig. 4.—Dead Spaces in Air Current About Triangular Prisms. The Direction of the Wind is Vertically Downward in This View.

investigations of air pressures upon planes, may be looked upon as an attempt, as it were, to make the molecules of the air visible to the eye. Prof. Marey, the well-known French scientist, appears to have been the first to demonstrate the course of air streams by the use of smoke; but although the results obtained were remarkable in many ways, in his method it is necessary to keep the speed of the air itself below three feet per second, so that the method is not applicable for high speeds. More recently work has been done in the same direction by Prof. Janacodate of Japan and also by Capt. Lafay. A very original method is used at the Koutchimo Aerodynamic Institute of obtaining records upon a thin plate covered with lycopodium powder and placed edgewise to the current, but in this case also low speed only can be employed. Some very interesting results have been obtained by P. Chichkoff of the St. Petersburg Polytechnic Institute, a report of which was recently given before the Aeronautic Congress at Moscow.

Mr. Chichkoff started out with the aim of producing visible records of air current upon the various surfaces by a method which should be independent of the speed of the air, this being an important point if the results are to be of real practical value. In the course of this work he devised a very ingenious method, making use of certain chemical reactions. This consisted in passing a suitable gas over plates treated with solutions of various kinds. Thus, for example, ammonia may be passed over paper impregnated with nitrate of mercury which is changed in color by the reaction. This paper is pasted on a plate which serves as a support to hold the solid body, such as a wood block placed in the path of the air current. According to this arrangement the prepared plate lies parallel to the air current and therefore offers practically no resistance to the stream of air. The air current employed is taken from a blowing box in the usual way and the plate and blocks are set before the blowhole, while a suitable proportion of ammonia and gas is introduced into the air current. In this way a shadow-pattern is produced upon the prepared paper surface by the action of the ammonia gas, the particular form of the pattern depending upon the velocity and character of the air current around the obstacle. However, the image thus obtained furnishes only a rather vague indication of the process which is going on around the block. The paper, after the action thereon of the ammonia, shows merely a more or less uniform color change in front of the block and at the sides, and an unaffected zone in the rear. The path of the individual air particles, the determination of which was the principal object of the experiment, could not be thus observed. Mr. Chichkoff therefore found it necessary to resort to the same expedient that had been used by Marey and Lafay, i. e., to divide the air current into a number of separate streams by means of cross partitions. But in the course of his experiment, Mr. Chichkoff improved on this method, using first of all a small tube laid across the air current and in front of the edge of the plane under examination. By means of this tube, which was provided with a set of small holes measuring

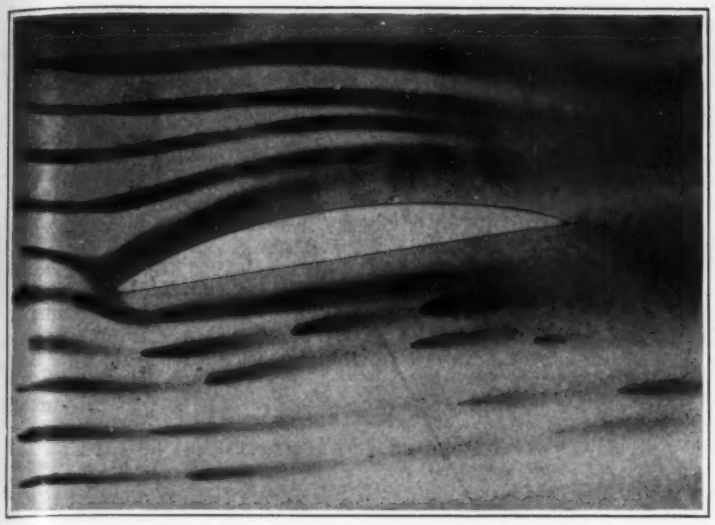


Fig. 5.—Stream Lines of Air About a Circular Segment Inclined to the Direction of the Wind. Speed, 220 Feet per Second.

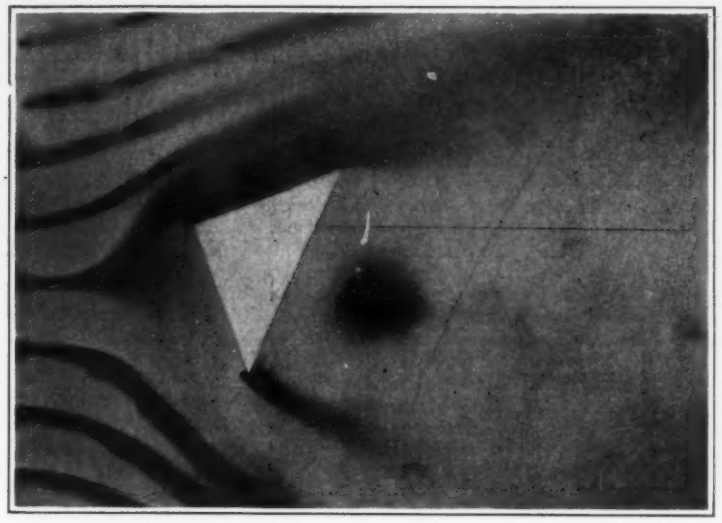


Fig. 6.—Stream Lines Around Triangular Prism. Note the Dead Zone Behind the Prism.

4/100 of an inch in diameter, and placed 16/100 of an inch apart, a number of separate streams of gas were projected and caused to flow along over the surface of the plate covered with prepared paper. These streams of gas are carried along by the main air current, and made to pass over the plate and there produce dark streaks. The effect is shown, for example, in Fig. 1, in which the gases flow from left to right. The obstacle placed in the path of the air current was shaped like the segment of a circle and was inclined at about 12 degrees to the current, which had a velocity of 220 feet per second. The result thus obtained was not entirely satisfactory, the gas gradually diffusing as it passes along, so that the record becomes hazy and finally obliterated before the back edge of the obstacle is reached. But after repeated efforts, Mr. Chichkoff finally found the means to overcome these drawbacks and obtained very excellent records. Our illustration, Fig. 3, shows a view of the wind box which is supplied with air from a suitable source and has an opening in front from which a practically uniform air current is blown out over a suitable area. The test obstacle is a long piece of wood having various profiles, such as a segment of a circle, a triangle, etc. This is placed across the mouth of the box. Attached to the obstacle is the thin metal plate covered with paper as described above. A stream of air is bubbled through a bottle of ammonia, so that it carries with it a charge of ammonia gas. It then passes through a rubber tube to a small glass tube ending in a very fine point. This tube is held perpendicular to the test plate and has a single small hole of 4/100 of an inch in diameter. Through this a very fine gas stream is delivered on the plate. With a little practice it is not difficult to find the correct position in which to hold the tube so as to get the best possible effect. Using this arrangement and moving the gas jet from point to point, wherever a record was to be made, Mr. Chichkoff succeeded in obtaining exceedingly clear records of the air movement in the space surrounding the test obstacle. The method followed is first of all to mark with a pencil a number of points in front of the obstacle, as starting point from which to begin one's observations. These points will be seen marked on the extreme left of Fig. 2. A tube is then placed opposite each of these points in turn, and a streak of about ½ inch in length is obtained. The course of this streak is then followed up by hand with the tube, and so on, until a complete set of flow lines is obtained. Instead of studying the conditions in front and around the obstacle, it is of course equally possible to make observations at the rear and to obtain a representation of the vortex movement in what is known as the dead zone. Images obtained here are shown in Fig. 4, the obstacle in this case being a prism of triangular cross section. The prism is placed in two different positions in the air current, with a wind speed of 35 meters (250 feet) per second. It is best in this case to introduce the gas directly into the dead zone in order to obtain a clear image.

Mr. Chichkoff's results represent a very valuable contribution to the general study of air movement, and his method has the great advantage of being very easily carried out and furnishing a permanent record.

Conduction of Electricity Through an Insulator

By P. S. Helmick

FEW persons think of the flow of an electric current, without picturing some metallic medium, as a lamp-cord, or a telephone wire, through which it may pass.

It is the purpose of these notes to supplement that view, by illustrating how conduction may, as proved by the results of several experiments, take place across a medium usually classified as a dielectric, and through which no ordinary electric current can flow.

Air is usually regarded as an excellent insulator, but every one has seen a spark leap across an air-gap, under the influence of an electromotive force of several thousand volts. This phenomenon is usually explained, by assuming that there are always a few ions, or "carriers of electricity," which, under the action of an electric current, are imparted a higher velocity, and are thus enabled to break down the molecules of the air into still other ions, until there are enough present to carry a current, which is really the spark.

In the *Philosophical Magazine* of August, 1912, Prof. R. W. Wood describes methods whereby he was able to detect conduction through dielectrics. He "half-silvered" thin quartz plates, and then, by successive rulings and cross-rulings, broke up this thin deposit of silver into small squares with sides of 0.001 centimeter length Yet the electrical resistance after ruling, was practically the same as before, although the cuts extended cleanly and distinctly through the silver. Of course, conduction must have taken place, to account for the constancy of the resistance.

He then deposited a film of 0.3 centimeter wide, having a resistance of 10 ohms, upon a glass plate, and after making 20 diamond cuts, of width 0.00003 centimeter across it, the resistance had increased but 3 ohms. Conduction had taken place at the low potential of 0.001 volt. With cuts 0.00006 centimeter in width, however, no trace of conduction was found.

Prof. Wood suggests that possibly the conductivity at the above low voltages might possibly be explained by the "discharge from points" phenomenon, for the minute irregularities upon the edge of the metallic deposit may be assumed to act as points.

He accordingly began experiments with "optical flats" of highly-polished, glass-hard, speculum metal which deviated from true planes by less than 0.0000015 centimeter. When the plates were separated by two quartz fibers, each some 0.000015 centimeter in diameter, a potential of 1 volt produced a current of several milliamperes. The current increased rapidly and steadily as pressure was applied to the planes, although it returned to exactly its original value when the force was removed. Conduction was also observed with finely powdered sulphur, with quartz dust, and with lycopodium spores. With small flakes of extremely thin mica, conduction took place in the neighborhood of 0.00075 centimeter under a potential of 1 volt.

Prof. Wood concludes that the effect is caused by the "presence of an atmosphere of electrons in the immediate proximity of metallic surfaces."

Following out the experiments and suggestions made by Prof. F. C. Brown, Mr. H. H Blanchard and I were enabled to investigate along the same lines, using two brass cylinders, each 0.6 centimeter in diameter and having one perfectly plane base. The true surface of one of the cylinders was dipped in the finely sifted dielectric material with which the cylinders are to be kept from metallic contact—in this case sulphur and precipitated selenium—the majority of the minute particles blown off by means of compressed air, and the other cylinder set gently on top of the first.

A Dolezalek quadrant electrometer, having a capacity of 80 centimeters, was then charged to a potential of 4 volts and connected in parallel with the cylinders. The latter, having a capacity by virtue of the small film of dielectric and air, receives some of the charge from the electrometer, so that its reading is diminished—just as any charge distributes itself over two bodies which are in electrical contact. It is then possible to obtain the distance separating the plates from the respective readings of the electrometer, the capacity of the instrument and the cross-sectional area of the cylinders:

Let C_1 be the capacity of the electrometer,

C_2 the capacity of the cylinders and air-gap,

d_1 the reading of the charged electrometer,

d_2 the reading of the electrometer after C_1 is connected to C_2, and l the distance separating the cylinders whose cross-sectional area = A.

As d_1 and d_2 are comparatively small, $C_2 = \frac{C_1(d_1 - d_2)}{d_2}$.

But $C_2 = \frac{Ak}{4\pi l}$,

Combining, $l = \frac{A d_2}{4\pi C_1(d_1 - d_2)}$.

As a check method the particles were also measured by means of a micrometer eye-piece and a mean value of l obtained

Below are the results of our experiments.

The above data indicate that with a potential difference of 4 volts, the maximum distance in ordinary air that the cylinders can be separated, in order that conduction may take place, is in the neighborhood of 0.0015 centimeters, as proved by the results in using both selenium and sulphur to separate the cylinders.

Now to explain the apparent inconsistency between the observed and the calculated value of l. The observed value with the micrometer eye-piece means that the cylinders are, as far as our human senses are concerned, that distance apart, while the calculated value indicates that they act as though situated from thirty to one hundred times nearer. This means that just outside the plane of the cylinders there must be located a swarm of conducting particles, or electrons, which can carry the charge from one cylinder to the other.

From these results then it appears advisable, in order to explain this kind of conduction with the most facility, to accept Prof. Wood's hypothesis and assume that conduction may easily take place across two metallic electrodes separated by an insulator, providing the distance lies within a certain constant limit.

Dielectric Used to Separate Cylinders.	Sample No.	Electrometer Zero.	C_1 Charged.	C_1 and C_2 Mixed.	l by formula, centimeter.	l by microscope, centimeter.	Remarks.
Sulphur	1	220.	283.	240.	0.000131	....	No leakage.
	1	228.5	282.5	241.5	0.0000869	....	Slow leakage.
	1	228.	282.	245.	0.000129	0.0015	Very slow leakage.
	2	273.	323.2	273.	0.0000000	0.0012	Conducting.
	3	272.	324.8	303.0	0.00040	....	.....
	3	272.8	325.3	303.0	0.00038	0.0027	.....
Selenium	4	270.	322.	270.	0.000000	....	Conducting.
	5	270.	321.	275.	0.000039	....	No leakage.
	5	271.	321.	273.	0.000013	....	No leakage.
	5	270.5	321.	270.5	0.000000	....	Conducting.
	6	271.	322.	275.	0.0000218	....	.....
	6	271.	320.	271.	0.000000	0.0015	Conducting.
	7	271.	323.	296.	0.000261	0.009	No leakage.

Airship Envelope Fabric*

Its Manufacture and Requirements

An airship envelope fabric must be impermeable to gas, be strong and yet light, and be as little affected as possible by physical actions such as the influence of heat or cold and light, or by any chemical changes which may take place either inside or outside the envelope. Cotton fabric is the material which is, at present, almost exclusively used for airship envelopes; it must, however, be specially prepared and treated so as to be suitable for the particular work it has to perform. In the course of its manufacture, the cotton fabric itself must be the subject of great care and attention if a satisfactory envelope material is to be obtained. The threads constituting the fabric must be fine, of uniform thickness throughout, and without knots or joins. Should a thread break in the process of weaving, it is important that no reassembling of any kind should be made, but that the whole line should be retaken from its origin. Great care must also be exercised in order that the envelope material may be of uniform thickness; and some of the modern methods employed in the manufacture of airship envelope fabric ensure that the variation in its thickness is always within one tenth of a millimeter.

IMPERMEABILITY AND STRENGTH.

After the best possible cotton fabric has been obtained, the next step is to render it impermeable to gas and to ensure that this impermeability is of a lasting character. Cotton fabric is made impermeable by treating it with a rubber solution; and in the manufacture of modern airship envelopes, cotton fabrics of double thickness are almost exclusively employed. The double thickness material is formed by uniting together two layers of single thickness each, and, in order to obtain it, each layer of fabric is treated separately. The fabric which will be on the outside of the envelope is covered with a layer of rubber on one side only, while the one which will be on the inside of the envelope is covered with a layer of rubber on each of its sides. The two fabrics are then stuck together, rubber against rubber. The double fabric material thus consists of (1) a layer of rubber; (2) a layer of fabric; (3) a double layer of rubber; (4) another layer of fabric. The resulting envelope material has only one visible layer of rubber, which always forms the inside of the envelope. It is of the first importance that the rubber used should be very pure, as impurities assist disaggregation, as well as reduce pliability. It is now definitely settled that the vulcanization of the rubber coatings of airship envelope fabrics lengthens their life, and this process should, therefore, be carried out whenever it is possible.

The two fabrics treated with rubber, as already described, can be joined together in two different ways in order to form the required double-rubbered fabric. In the case of the German airships, the two fabrics are so joined that their threads cross one another diagonally, while it is the French practice to place them over each other in such a way that their threads are parallel to one another. The former method produces a material which is somewhat heavier than the latter for a similar thickness, because strips of rubbered material have to be stuck over the places where the diagonally-placed pieces meet. It is admitted, however, that this airship envelope material is somewhat stronger than the one with parallel threads. But, on account of the shape of an airship envelope, the greatest pressure of the gas in its interior may be supposed to be exerted along a direction parallel to its axis. It is, therefore, in that direction that the threads of the panels forming the envelope should run. Since it is possible to have all the threads of the double-rubbered cotton fabric running in the same direction if it has parallel threads, it would seem that whatever increase in strength is obtained by the use of the diagonally-rubbered fabric that gain is greatly discounted by its greater weight compared with that of a fabric of the same thickness with parallel threads.

Some interesting results concerning the strength of the two kinds of airship envelope material have been recently obtained at the National Physical Laboratory, where the fabrics were tested under combined stresses at right angles, since that condition obtains in airship envelopes. An exhaustive set of compound stress tests was made on a series of bags of double-rubbered cotton fabric with parallel threads with the object of investigating the law according to which the stress ultimately causing breakdown is lowered by the presence of a less stress in a direction at right angles. It has been fairly settled that for a parallel double fabric the limits of a compound stress may, with an allowance of 5 per cent, be taken as the limits of simple tensile strength of warp and weft, the limits of tensile strength being those obtained from tests of elongated specimens. As regards the double fabric with diagonal threads, no very definite conclusion has yet been arrived at, but it would seem that, as a rough approximation for working purposes, the bursting stress of the diagonal material may be taken as being about 1.4 times the strength of the same material as determined by single tensile test.

Although the manufacture of rubbered cotton fabric is of relatively recent date, the fabrics that can now be obtained possess the requisite strength and impermeability when they are new. The problems which are now awaiting solution are what precautions must be taken in order to lengthen the life of the rubbered cotton fabric, and how to determine whether an envelope material, which has been in use for some time, can be employed with safety.

In order to answer the first of these two questions it is necessary to determine the causes which may be responsible for any alteration in the qualities of rubbered fabric. An examination of the different changes in the properties of the material shows that they may be due either to physical or to chemical actions. Among the first are changes due to the effect of light and of temperature, especially cold; while the changes arising from chemical actions are due to the influence of acids and of certain impurities that may be present either in the rubber itself or in the gas with which the airship is inflated.

EFFECTS OF LIGHT.

It has been found that violet and ultra-violet rays of light act on rubber. It is therefore important that that side of the material which forms the outside of the envelope should be proofed with substances which will stop the violet and ultra-violet rays of the sun. Three substances can be used for that purpose—lead chromate, aniline, and picric acid. In order of efficiency, picric acid stands first, next comes lead chromate, and then aniline. But on account of its being a violent poison, picric acid cannot be employed, and at present, therefore, the choice lies between lead chromate and aniline. The French constructors prefer lead chromate and the Germans aniline. Each has its advantages and disadvantages. If small balloons, covered on the outside with a layer of either of these two substances, are exposed to light, it will be found, after some months, that the rubbered envelopes, protected by lead chromate are still in a good condition, while those protected by aniline have rapidly lost their color, and the rubber of the material, being no more protected, has undergone a complete change and lost most of its important qualities. Lead chromate has, however, a disadvantage compared with aniline, in that it must be applied on the fabric before the layer of rubber. Now in order to vulcanize the layer of rubber heat must be applied, and this results in blackening the protective yellow color of the lead chromate. The rubber of the fabric protected by lead chromate cannot therefore be vulcanized, and this is a disadvantage of the use of this protective substance, since the life of rubber is lengthened by vulcanization.

It will thus be seen that the choice between lead chromate and aniline is not a very easy one, and research is being made, in various quarters, to discover a pigment free from the disadvantages of both. In this connection, some remarkable experiments were recently made at the National Physical Laboratory with five specimens of rubbered fabrics. Of these, three had an external protective coloring of yellow, one was proofed outside with red rubber, and one had no protective coloring whatever. Two sets of samples were tested; one set was exposed only in fine weather, while the other was left out in the rain, and watered on days when no rain fell. The most noteworthy deduction from these experiments is that rubbered fabrics usually show a marked improvement in impermeability at a stage when they are almost completely perished, which is followed by very rapid deterioration and complete loss of gas tightness. This was shown especially clearly by the fabric with no protective pigment, but clear evidence was obtained also in the case of some of the protected fabrics, at a much later period of exposure, especially in the wet series of tests. Hence a marked improvement in the gas tightness of the rubber proofed envelope material must be regarded with grave suspicion. The beneficial effect of the yellow coloring was plainly shown; the loss of tensile strength in the unprotected or badly protected fabrics was very much greater than in the yellow pigmented cloths. The injurious effect of rain and light together was appreciably greater than that of light only.

EFFECTS OF TEMPERATURE.

Changes in temperature also affect the qualities of rubbered fabrics. Thus it has been found that after a long period of cold weather with a temperature reaching at times from 12 deg. to 14 deg. Cent. below zero, during which an airship had been left inflated in its shed without any periodical refillings, the envelope had ceased to be gastight. It was further observed that the parts of the envelope that lost most of their impermeability were especially its upper portions and its nose, the fabric forming the sides and the under portions of the envelope being very little affected. Such a fact points to an elementary precaution which ought always to be taken, namely, the maintenance of the interior of an airship shed at an equal temperature; and all airship sheds should therefore be provided with a suitable heating apparatus. It is now also definitely settled that rubbered fabric is less affected by intense cold if the rubber has been vulcanized. Non-vulcanized rubber is also more greatly affected by heat than vulcanized, especially if the temperature rises to 50 deg. or 60 deg. Cent. It is now also fairly proved that the bad effects of low temperature on rubbered fabrics are increased if the lowering of the temperature is accompanied by the presence of a large quantity of moisture, and if the inflating gas itself contains certain impurities, giving rise to injurious chemical actions.

OXIDATION.

Rubber belongs to that class of compounds known to the chemist as hydrocarbons, and through the action of a number of substances—especially of ozone—it can be oxidized. The oxidation, however, is more difficult if the rubber is vulcanized, and in this respect all natural rubbers are far from being equal in value. There are in rubber certain ferments which play an important part in the oxidation. Among the different kinds of rubber, Para rubber is nearly free from those oxidizing ferments, and it is therefore the kind to be used in the manufacture of rubbered fabric for airship envelopes.

All acids being oxidizing agents, it is important that the lead chromate used as a pigment to stop the destructive action of the violet and ultra-violet rays of sunlight should be perfectly neutral; but, as a matter of fact, the most active oxidizing agents are to be found among the impurities which may be in the hydrogen used for the inflation of the envelope. Among these impurities are ozone, if the hydrogen is obtained by electrolysis, and such gases as sulphurretted, arseniated, antimoniated, and phospheretted hydrogen, which may be present if the hydrogen has been obtained by the action of sulphuric acid on iron. These last-mentioned gases have only a small action on rubber if they are perfectly dry; such is not the case, however, if water vapor is present in which they may dissolve, the sulphuretted hydrogen giving rise to traces of sulphuric acid which may have disastrous effects on rubber. Besides, with the intervention of cold the damp gas containing these powerful oxidizing agents condenses on the coldest parts of the interior of the envelope, which are naturally its upper portions and its nose which are nearest to the roof and to the end side of the shed. The importance of having the whole shed equally warmed and well closed is thus clear.

TESTS FOR RUBBERED FABRIC.

Three methods may be employed to examine the alteration that may have taken place in rubbered airship fabric. The first consists in a microscopic examination of the material, and the other two are based on its solubility and viscosity in benzine and in acetone respectively. If the rubbered airship material has not been exposed to any injurious influence the two single fabrics forming the double fabric can be separated from each other only with difficulty, but, when this is done, it is found that the separation is clear and complete. Under the microscope the two layers of rubber which have been separated from each other are seen to be perfectly homogeneous, and on the line of contact, where the separation ends, the microscope enables one to see the fibers of the gluing rubber stretched from one fabric to the other—their length and regular disposition testifying to their elasticity. If, however, the airship envelope material, instead of being in a perfect state of preservation, were in a perishing condition, the separation of the two fabrics constituting the envelope material could be made easily, and in that case a microscopic examination would show that the separation is not a clean and complete one, but that particles of from each layer adhere to the other fabric.

* Reproduced from the *Engineering Supplement* of the *London Times*.

The New Diesel Engine*

Designed to Obtain Higher Powers from Small Cylinders

THE Diesel engine proper has practically passed away. All those now made in that name are widely different from the original, though the name stands with some people to distinguish the type of explosion engine in which the fuel is injected after air is compressed to such a degree as to create an ignition temperature. Dr. Wilhelm Schmidt now proposes a new Diesel engine, "points" of which may be summarized thus: (1) The main cylinder will be charged with highly compressed air; (2) the temperature will be lower before explosion and higher in the exhaust; (3) spark ignition may be required; (4) the exhaust will drive an air compressor. The object is to get higher powers from smaller cylinders. The patent is, like many German ones, not for a thing made or designed, but for an idea. It may be called a patent essay rather than a patent engine. As an essay it is learned and interesting and sheds light on several questions, though it leaves us in the dark as to how to make the engine patented. We will try to present it in a simplified style without going too far from Dr. Schmidt's wording.

At present the combustion air in the working cylinder is compressed to 30 to 35 times its initial pressure. It works with a considerable degree of economy, but in comparison with the large cylinders and moving parts, develops comparatively small power. For this reason the making of such engines of high power offers great difficulties. The possible cylinder dimensions, in particular, soon reach a limit, so that high powers can only be attained by increasing the number of cylinders and cost per horse-power-hour. Dr. Schmidt now hopes to make engines more economical and smaller and lighter for the same power. It has already been proposed to increase the initial pressure of the air to be fed to the cylinder by preliminary compression, and at the same time to reduce the compression ratio of the combustion air compressed in the cylinder. A preliminary compression of six to eight atmospheres was adopted and a compression ratio in the combustion cylinder varying from 1:15 to 1:6.5. The burned gases were used in a combustion product engine working like a hot-air engine, which had (1) to effect the preliminary compression and (2) to deliver power to the shaft; the engine as a whole being made as a compound engine in which both the temperature drop and the work were divided. This engine was a complete failure, on account chiefly of the attempt made to compound it after the manner of a compound steam engine. The combustion product engine, which formed the low-pressure part of the compound engine, was not suitable for high powers owing to its lack of economy. The exhaust gases entered the low-pressure cylinder at a pressure of about sixteen atmospheres and a temperature of 1,300 degrees, with the result that not only the pipes connecting the cylinders, but also the admission valve of the low-pressure cylinder and the large low-pressure cylinder itself, were made red-hot and had to be artificially cooled, causing great heat loss. At the same time, in the combustion cylinder the losses were increased, because the exceptionally low expansion ratio, due to the low compression ratio, called for a late cut-off (almost 50 per cent), and this in turn involved large cooling losses and a high temperature of the gases during the whole stroke.

According to the new invention, the compression of the combustion air in the cylinder is fixed at twelve to twenty-four times the initial pressure (two to four atmospheres). Preferably, the ratio of compression and the ratio of expansion dependent thereon are so chosen that the energy in the exhaust gases may drive the preliminary compression pump. The compression pressure, which according to present practice amounts to thirty to thirty-five atmospheres, is thus increased to sixty atmospheres or more; the reduction of the ratio of compression in the cylinder to about twelve to twenty-four times proceeding with the increase of the initial pressure of the combustion air. The increase of the initial pressure allows a larger weight of air to be introduced with smaller cylinders, an element on which, apart from the quantity of fuel, the output of the engine essentially depends. For example, the increase of the initial pressure to about four atmospheres absolute, other things being equal, reduces the stroke-volume to a quarter of that hitherto usual. The reduction of the compression ratio is thus simultaneous with a decrease of the expansion ratio, the cut-off takes place later, a moderate retardation of the cut-off as compared with what is usual being desirable. Theoretically, the reduction of the expansion ratio is a retrograde step, but the disadvantage is counterbalanced by other advantages. For example, taking the initial pressure of the combustion air as before at four atmospheres absolute, then for the same weight of air the cooling area of the cylinder walls of the new engine amounts to only one half and the areas of the cover and the piston to only a quarter of the present practice. The cooling losses, now about 33 per cent of the total heat, are thus reduced by one half, while the heat available for work in the cylinder is correspondingly increased.

With the smaller cylinder a more perfect combustion will be obtained; the high compression pressure leads to an increased concentration of the oxygen molecules which makes the combustion more lively. The smaller cylinder also insures a more uniform mixture of fuel and air, and the later cut-off affords a longer period for combustion, so that after-burning during expansion is avoided. So much for the thermal advantages which would be gained.

Dr. Schmidt then proceeds to set forth the mechanical gains. The mechanical efficiency at present is low in comparison with other engines, the ratio of the brake horse-power to the indicated horse-power being 75 per cent and under. This low efficiency is due to the relatively large negative work of compression with an early cut-off, and to the high maximum pressures on the working parts in proportion to the power developed. The mechanical efficiency of the new engine will be higher, because both the negative work of compression and the maximum pressures are decreased. If the cylinder does not produce a sufficiently high temperature for ignition the air may be heated before admission. In some cases, the air may be cooled after the preliminary compression, in which case ignition must be artificially effected. Considerable work is required for the preliminary compression of the air, and this must not fall on the engine proper. For this reason the exhaust gases are used in a combustion product engine (piston or turbine) which in turn drives the compressor (piston or turbo-compressor). The exhaust gases will have a much higher pressure and temperature than in engines hitherto proposed.

It must be particularly noted that the object of the new engine cannot be attained merely by increasing the initial pressure of the air or by merely reducing the ratio of compression; the results can only be attained by the simultaneous modification of both. The new method of working is suitable for all, but specially applicable to two-stroke engines, since they are already provided with a compressor plant. Dr. Schmidt's specific "claims" are: (1) A method of working according to which the ratio of compression of the combustion air compressed in the working cylinder is fixed at twelve to twenty-four times the initial pressure of two to four atmospheres. (2) A method of working as in claim (1), the ratio of compression and also the ratio of expansion being so chosen that the energy remaining in the exhaust gases is sufficient for driving the preliminary compression plant without additional assistance.

* Reproduced from *The Practical Engineer*.

The Waning Supply of Gasoline*

And the Use of Kerosene for Internal Combustion Engines

By John A. Secor

THE power-driven vehicle can no longer depend on its present fuel. The demand for gasoline has overtaken production. During the last decade the oil market has been readjusting itself to radically new conditions. This has been brought about by many new applications of oil products for developing heat and power. Crude oil was formerly looked upon simply as the raw material for the production of illuminating and lubricating oils.

The invention and perfection of the gasoline motor, and its application to the automobile and power boat, dates back to the high-speed gasoline engine of Gottlieb Daimler, as shown at the historic Mackay-Bennett Automobile Race from Paris to Bordeaux. Europe gives Daimler full credit for his work by remembering him as the "Father of the Automobile."

The introduction of the Daimler motor opened up an entirely new market for the lighter oils, gasoline and naphtha, which developed within the short period of ten years into larger proportions than the most optimistic oil men ever dreamed of. Under these conditions the inexorable law of supply and demand brought about a price level for the volatile distillates far in excess of former values.

For nearly half a century price advances were extremely moderate, as the fluctuating market quotations of gasoline were ordinarily within narrow limits. An approximate general statement would be that the mean increase in price barring fluctuations was about one mill per annum per gallon—equaling one per cent per decade. The total sum of these price increments had brought gasoline from say 5 cents up to 10 cents per gallon in tank car lots at the close of 1911.

But last year an unparalleled increase of 6 cents raised the wholesale price to 16 cents per gallon at the close of the year. In 1912 the wholesale price, therefore, advanced 60 per cent, and the retail price about 75 per cent.

Furthermore, it should be noted that the low cost gasoline of the early days varied in gravity from 70 deg. to 76 deg. Baume, averaging 72 or 73 degrees, while the gasoline now marketed is about 10 degrees lower. This 62 or 64-degree product was formerly sold under the trade name of benzine.

United States Government reports show that the advancing price of gasoline is due solely to inevasible laws of supply and demand. No corporation or combination of corporations is responsible for the fact that demand has overtaken production, and that further increases in prices are now impending.

American gasoline and naphthas were formerly obtained solely from high grade paraffine crudes of Pennsylvania and Ohio. These are the most valuable oils in the world, and highest grade Pennsylvania crude now actually brings the same price as refined kerosene in bulk.

But unfortunately Pennsylvania production has fallen from 32,000,000 barrels in 1891 to about 9,000,000 barrels at the present time. However, at present prices even this decreased production represents over $18,000,000.

Ohio has decreased in production from 24,000,000 barrels in 1896 to less than 9,000,000 barrels during the past year.

Again, the zenith production of our own State of Indiana was in 1904 over 11,000,000 barrels, but the present yield shows a shrinkage of nearly 90 per cent from maximum.

The United States Geological Survey states that the general decline in production "would doubtless have been much greater but for the effort to apply laws of supply and demand by increases of prices. Prices advanced so greatly during the year as to stimulate drilling, even in the old New York and Pennsylvania pools, and so checked the decline. Formerly this plan has not been so successful. In the mid-continent field also, it checked the decline, so that the product will come within 4,000,000 barrels of the maximum output."

Canada, also, has fallen off one third from her highest production of five years ago, and the only new field in sight is Tampico, in Mexico, which has grown from nothing three years ago to 6,000,000 barrels in 1912.

About the only home fields not showing decreased output are in California and Oklahoma. Three fifths of the total yield now comes from these two States. And even the increased output of Oklahoma was insufficient to prevent a continuous reduction of stock on hand in 1912. Ninety per cent of the entire output of more than 220,000,000 barrels were crudes which yield a very low percentage of gasoline.

* Extracts from an address delivered before the Society of Automobile Engineers (Indiana Section) at the Claypool Hotel, Indianapolis, February 18th, 1913.

The following market prices of eastern, mid-continent, and western crudes are fairly indicative of their relative gasoline content:

Pennsylvania	$2.05 per bbl.
Indiana	1.23 per bbl.
Oklahoma and Kansas	.83 per bbl.
California	.35 per bbl.

These prices of crude oil were correct as of January 25th, 1913. Since that time Pennsylvania crude oil advanced 7 cents a barrel on each of three successive days, standing now at $2.50, and three-dollar oil is freely predicted.

In order to obtain a single gallon of gasoline from refinable California petroleum, it is necessary to produce as by-products nine gallons of kerosene and thirty gallons of residual oils. Notwithstanding the steadily increasing output of western oil the price of gasoline on the coast continues to advance. It is now 30 cents per gallon at retail.

Large shipments of Texas oil formerly came to the Atlantic seaboard in tank steamers, but these shipments have decreased, as the Texas oil yield is now less than one third its 1905 output. In view of the Texas shrinkage it is obvious that the opening of the Panama canal will furnish a large eastern market for California oil, but it is equally obvious that under existing conditions that will not materially affect the gasoline situation.

There are five different methods of increasing the normal visible supply of gasoline.

One is importation. The Standard Oil Company has imported some Russian naphtha, but Russia has no more to spare, as her own oil output is diminishing to such an extent as to increase the price 100 per cent in the last two years, and to warrant the Russian government in the promotion of alcohol production. The Shell Oil Company of England has also shipped some gasoline from Borneo to Canada, but the total quantity available abroad is insufficient for its home demands and America is still exporting gasoline to foreign markets at the rate of 15 to 20 million gallons per month.

Another and more promising means of obtaining gasoline is by increasing the total yield of American crudes. A yearly production of 300,000,000 barrels in the United States is probably being approached faster than even oil men generally believe. But the largest increase in the production of gasoline in one year has never been more than 5 per cent, while the production of power driven vehicles will in all probabilities represent an increase this year of around 100 per cent. Furthermore, as already shown, the supply of gasoline yielding crudes is rapidly decreasing and the increased crude output will consist of Oklahoma and California asphalt oils, having insufficient gasoline for existing requirements.

The third means of supplementing the gasoline supply is the production of gasoline from kerosene. Chemists have known for some time that it was entirely feasible to extract gasoline from the chemically complex kerosene, as well as from coal, coal tar, and even wood. It is simply a question of cost, and of the profitable disposal of resultant by-products. Gasoline is now being made from kerosene, and a further increase in price will stimulate an increased output.

A fourth source of gasoline supply is its manufacture from natural gas by compression, and its subsequent condensation to a liquid form. It is claimed that this process produced 13,000 gallons in 1910, which was increased to 50,000 gallons in 1911, and about twice as much in 1912. Some of the richer gases produce as much as 8 gallons per 1,000 cubic feet, but the average is from 3 to 5½ gallons. By triple and quadruple compression up to pressures as high as 400 pounds, very light liquids up to 84 deg. Baumé are produced, these being slightly more stable than the products of fractional distillation.

The fifth and last means of increasing the available gasoline supply is by lowering its Baumé gravity. It is probable that the specific gravity of commercial gasoline will be dropped another notch by next summer. Much of the liquefied gas gasoline is used for blending with heavier distillates, and it naturally requires other than gravity tests to determine the characteristics of such blended gasolines.

With the exception of importation these various methods of augmenting the available quantity of gasoline are now in active operation, and every increase in price is a stimulus to additional output.

This brief review of market conditions shows that the problem of an adequate supply greatly overshadows the problem of the increasing cost of gasoline.

Fortunately we have two alternative liquid fuels immediately obtainable. Alcohol and kerosene oil offer an ample supply of satisfactory fuel to the power-driven vehicle. We need not discuss alcohol at this time, further than to point out that it is a very good fuel and can be used advantageously if gasoline advances to 20 or 25 cents wholesale. In fact there is no valid reason why alcohol should not be used to-day in cars selling around $5,000. Of course, special engines with appropriate compression are required, as gasoline engines are not adapted for alcohol.

Predictions heretofore made in regard to denatured alcohol as a fuel have not yet materialized. Nevertheless, it is probable that alcohol alone could hold down the price level of gasoline from advancing appreciably beyond 25 cents to 30 cents in tank car lots.

But the one best fuel is oil.

Oil combines more advantages than any other. It is the fuel of the future and the fuel of to-day. In comparison with gasoline or alcohol it is much cheaper; safe; better adapted for shipment; more uniform in quality; more highly concentrated; more powerful and above all more abundant in all localities.

Even in the far distant future, when the crude oil output falls below the world's demand for liquid fuel, a practically unlimited source of oil will be the great oil-bearing shales which cannot be worked profitably at the present low price of kerosene.

After many years of observation and experience I am convinced that as a medium for generating power for transportation, on land or water, mineral oil or kerosene is the most valuable general purpose fuel known to commerce. This statement is made in full recognition of the fact that the oil engine has always had less commercial popularity than either the gas or the gasoline engine.

In former days the oil engine was heavily handicapped by the high price of both crude and refined oil. Gasoline was then a by-product selling at 5 cents or even less. But the lapse of time has completely reversed the market relations of gasoline and oil. Oil production is in excess of consumption. Kerosene is now the by-product and is quoted at 60 per cent less than gasoline.

Of several hundred experimental or commercial oil engines made since the days of Brayton in 1876 nearly all were successful within certain limitations. The detracting feature in these engines is the lack of flexibility, which also characterizes the common kerosene lamp. It may be conceded that gasoline is by no means a flexible fuel in comparison with gas, but it is much superior to kerosene as heretofore used for illumination in lamps, or for power in combustion engines. There is no difficulty in operating a kerosene lamp properly adjusted to constant conditions. And there is not the slightest difficulty in using oil fuel in any ordinary gasoline automobile when there is no carbon in the combustion chamber of spark plugs, and when fuel mixture, compression, temperature, atmospheric humidity, power output, engine speed, spark intensity and position, and fuel density are correct constant.

Under ordinary working conditions any ordinary engine with practically any good gasoline carbureter can use kerosene if kept at medium speeds. A car was thus taken from New York to Boston, operating entirely on kerosene except for starting. But the lack of adequate flexibility becomes increasingly apparent as the speed and power are reduced. If slowed down the car will not "pick up."

One of the chief differences in the operation of stationary and automobile motors, respectively, is that the former are generally governed on the hit-and-miss principle, whereas the latter are governed or controlled by means of the throttle. Hit-and-miss governing is a great aid in the successful use of kerosene, because every charge taken in by the engine is a full charge, hence the charge is always equally proportioned and is also compressed to the same pressure. Therefore, with a hit-and-miss governor it is only necessary to get carburetion right for one particular set of conditions, while with control the problem is much more complex.

Nearly all engineering authorities have held that in order "for internal combustion engines to work successfully with any of the kerosene oils they must be provided with some form of volatilizer, vaporizer, gasifier or its equivalent," or in other words, supplementary means of heating the fuel, which would be unnecessary in a gas engine.

Brayton heated his oil by passing it through a heated gauze diaphragm. Oil engines of the vaporizing type, such as the Hornsby-Akroyd, use a vaporizer. In the Diesel the increased heat is obtained by high compression within the combustion chamber. Most recent experimenters employ exhaust-heated carbureters.[1]

Prof Hutton has shown that, "The only difference between an internal combustion engine using kerosene oil and the gas engine proper is that the oil engine requires a device whereby the liquid fuel may be atomized or pulverized so as to be introduced into the mixture in a state of such division that the liquid fuel in a condition analogous to a mist shall be distributed all through the mixture of oil and air in such a condition that the propagation of flame shall be instantaneous or practically so, as it is in a mixture of air and gas."

[1] Another form of engine designed for the use of kerosene was described in the SCIENTIFIC AMERICAN SUPPLEMENT for February 15th, 1913, p. 105.

International Congress of Mining

ONE of the largest of the great scientific and industrial congresses is to be held in London in the early part of June, 1915. This is the sixth international congress of mining, metallurgy, applied mechanics, and practical geology. These congresses take place at intervals of five years, and the last, which was brilliantly successful, was held at Düsseldorf in 1910, previous congresses having been held in Paris and Liége. The attendance at the Düsseldorf congress was more than 2,000, and it is anticipated that the attendance in London in 1915 will be equally large. An influential committee has been formed to make the necessary arrangements, and the movement is being actively supported by the University of London, Imperial College of Science and Technology, Geological Society of London, Institution of Mechanical Engineers, Iron and Steel Institute, Society of Chemical Industry, Institution of Mining Engineers, Institution of Mining and Metallurgy, Institute of Metals, South Wales Institute of Engineers, Cleveland Institution of Mining Engineers, West of Scotland Iron and Steel Institute, Staffordshire Iron and Steel Institute, Sheffield Society of Engineers and Metallurgists, and by numerous firms interested in the various industries represented.—*Nature.*

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